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Contents

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Rates and Regulations for Water Used in Air Conditioning

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A panel discussion presented on May 3, 1948, at the Annual Conference, Atlantic City, N.J.

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For years the operators of water utilities have looked with envy at the innumerable electrical load-building appliances that have been produced and placed on the market. At last, a load builder, air conditioning, has been developed which will add greatly to the revenue of water properties, and now certain groups in the industry start talking of "special rates" and "special regulations" to curtail this use of water. Are these men being short-sighted or do they have a real basis for concern? Is this a desirable type of load builder?

Outline of the Problem

Disposing of the comparison with the power industry first, their business is essentially to render a service; the water industry must not only render a service but also deliver a commodity, tons upon tons of it. Because the problem of transportation is added to that of service, no valid comparison can be made between the two types of utility.

The demands of air conditioning on the water system vary from city to city, depending upon the temperature of the water used. Thus, a community using wells with temperatures around 50°F. has a very different problem from one where the source is an impounded surface supply. In the community with the well supply, the cooling of the air may be accomplished merely by passing it over water-cooled coils. It has been found that such installations may require as much as 8 gpm. per equivalent ton of refrigeration. Compare this with the community which depends upon a surface supply: the temperature of the water is so high that the situation demands refrigerating equipment, which will require only approximately 2 gpm. per ton of refrigeration.

Geographic considerations have a great bearing upon the effect of air-conditioning demands on water systems. For example, investigation disclosed that, generally speaking, water plant operators in Canada are not particularly concerned about the problem. The daily temperatures are relatively moderate; the hot days are few and the summer season is short when compared with climatic conditions in the Mississippi Valley or the southern states. Identical buildings would require equipment of smaller capacity in Canada to effect the same comfort as in the Mississippi Valley. The air conditioner would be used to capacity for fewer days during the summer season, and the shortness of the season would further reduce the total days of use.

It is the author's opinion that everyone in charge of a water property should, if he has not already done so, make a careful survey of the physical plant and determine as nearly as possible just what the future may bring. Although air conditioning is not new, it was only a few years prior to the war that it began to receive wide public acceptance. The trend toward air conditioning had just started to gain momentum when the war brought it to an abrupt stop. Since the war, because of critical shortages in almost every class of material required to make such installations, the prewar momentum has not yet been equaled. Now is the time, therefore, to take stock and be prepared. If studies indicate that the probable air-conditioning demands will result in uneconomical operating conditions without controls, they should immediately be established. It is easy to get the customer to comply with reasonable regulations at the time the initial installation is made, but exceedingly difficult to get him to observe a new rule willingly after he has been using his conditioner for some time.

Air conditioning is here to stay even though the installations have so far been confined to a comparatively few industrial and commercial establishments. To meet competition, when equipment becomes more readily available and possibly less expensive, all retail establishments and more and more offices will employ conditioning. And it is not believed merely visionary to expand this prediction to include private dwellings. There seems to be no end to the possibilities for the demand for conditioning installations.

In studying this problem it must be remembered that the physical plant of the water property—that is, the source of supply, water treatment plant, storage facilities, heavy-duty pumping and distribution system—must be designed and built to handle the seasonal and daily peak air-conditioning load in addition to ordinary consumption and fire-fighting demands. The daily peaks in cities of the United States from which the author has received data indicate that air-conditioning loads will run from 22 to 100 per cent of the daily average plant output. This excess water is being used on peak days in a period of from eight to twelve hours. There is an economic limit on the size of plant that can be built to meet such loads and exist under the present rate structure. Such a limit will vary with each individual property.

Methods of Control

The definition of reasonable control is considered to be an individual plant

problem, but the author believes that prohibiting the use of water-cooled coils when wells are the source of supply is justified both economically and from the standpoint of conserving a natural resource. Such a prohibition would require the customer to install refrigerating equipment, which may be equipped with water conservation auxiliaries if conditions warrant.

Another approach toward conservation is the imposition of a surcharge for water used in air conditioning without conservation equipment. The proponents of this school of thought claim that, if customers desire to use the water wastefully and will pay the higher costs, the revenue so derived will support the additional plant facilities required. But if customers do not wish to pay these surcharges and install conservation equipment to avoid them, there will be only nominal demands placed upon the system, which may be readily absorbed by the existing plant. The difficulty in determining a surcharge that will equitably carry additional fixed charges and operating expenses to meet this demand is apparent and, when arrived at, would probably be so high that it is not worth the bother to compute it. Such a rate would very likely cause everyone to install conservation equipment immediately.

Illinois Study

Champaign and Urbana, Ill., depend for their supply upon well water having an average temperature of 54° at discharge. Although there is some rise in temperature by the time the water is delivered to the customer, it is still well within the acceptable range in which water-cooled coils may be effectively used. As previously pointed out, such equipment uses large quantities of water—as high as 8 gpm. per equivalent ton of refrigeration. In the late 1930's this demand began to present quite a problem and a study of controls was undertaken.

The results of this study and the action initiated to effect conservation have previously been reported (1). A very brief review will provide a background for understanding why the regulations adopted proved ineffective and new ones had to be developed.

The study disclosed that, under the present rate schedule (*see* Table 1), it is cheaper for a customer to take water at 58°F., use it and throw it away than to install refrigerating equip-ment with recirculation. It was also found that air-conditioning installations in which water from the city mains (at a temperature of 58°F.) is used as a direct cooling medium in extended surface coils will require 3–8 gpm. of water per equivalent ton of refrigeration; that conversion to mechanical condensing units with conventional shell and tube—or pipe—condensers would save 73 per cent of the water previously used; that if evaporative condensers were added to the mechanical condenser units, a further saving of 22 per cent would be effected, or a total saving of 95 per cent of the water used in the first installation described; and that over 60 per cent

TABLE 1

Champaign-Urbana Rate Schedule

Amount per Quarter *cu. ft.*	Rate per 100 cu. ft.
First 9,000	$.25
Next 9,000	.18
Next 9,000	.10
Over 30,000	.06

of the total air-conditioning installations employed in the United States in 1941 were either air-cooled or used cooling towers, evaporative condensers or the like, thus practically eliminating any demands for city water.

To force the customer to install refrigerating apparatus with a recirculating device, or conservation equipment, the Illinois Commerce Commission approved an application of the Illinois Water Service Company to deny any customer the benefit of the last two steps in the rate schedule unless such conservation equipment was installed. This established a surcharge and, although it increased some customers' bills as much as 150 per cent, it was still cheaper to use the water and throw it away than to install refrigerating and conservation equipment. The increased revenue so derived would not carry the fixed charges on necessary added plant investment and operation. Nothing had been gained. Two alternatives presented themselves: to revise the surcharge by actually computing an equitable rate on the basis of the actual plant investment plus operating costs required to supply the air-conditioning demand; or merely to restrict the use of water. A preliminary review of the factors that would enter into the establishment of an equitable surcharge indicated that the rates would be so prohibitive that, in effect, the result would be the same as establishing rules restricting the use of the water.

Regulations Adopted

Having reached this conclusion, in 1946 the company petitioned the Illinois Commerce Commission, requesting that the rule authorizing a surcharge be cancelled and submitting a set of regulations which was approved and has been found effective. These rules governing the use of water for summer comfort air conditioning or refrigeration read:

In all apparatus or equipment installed for the purpose of changing the dry bulb temperature or humidity content of the air, whether used in conjunction with summer comfort air conditioning or other refrigeration, the following regulations shall apply:

(*a*) The use of water is prohibited when used directly from the mains as a cooling medium in air washers or any type of equipment whereby the air to be conditioned comes into direct contact with sprays or wet surfaces, or where the water is used as the direct or indirect cooling medium in coils.

(*b*) The use of water is prohibited in all compressor-type refrigeration units having standard rated capacities * of $1\frac{1}{2}$ tons or less.

(*c*) All compressor-type refrigeration units having standard rated capacities * of from $1\frac{1}{2}$ to 5 tons may be equipped with water-cooled condensers using water from the mains; provided that not more than one such unit with such capacity and so equipped may be used in an air-conditioning or refrigerating system, except for emergency stand-by purposes.

(*d*) All compressor-type refrigeration units having standard rated capacities * of 5 tons or over shall be equipped with evaporative condensers, evaporative coolers and condensers, water cooling towers, spray ponds or other water cooling equipment so that all water from the mains is used for make-up purposes only.

(*e*) If other than compressor types of refrigeration units are used, the consumption of water from the mains shall be limited in amount to not more per ton of

* Note: in (*b*), (*c*) and (*d*) capacities shall be in accordance with conditions given in Standard A.S.R.E. [American Society of Refrigerating Engrs.] Testing and Rating Codes.

refrigeration produced than would be used by the compressor type described under (*c*) or (*d*) above when such type is operated under normal conditions.

Failure to comply with the above regulations shall be sufficient cause to discontinue service.

Regulations in Other Areas

The author mailed out 50 questionnaires from coast to coast in the United States and Canada to determine how air-conditioning demands were affecting plant operations and what was being done in the way of regulation. Forty-one replies were received, many expressing interest, but only a few indicated that they had given the problem any study. Where regulations were in force, the most common method used was to restrict the discharge of water into the sewer system to a very nominal amount.

In Reno, Nev., the per capita consumption increases from 400 gpd. in the winter to 1,000 gpd. in the summer. No statement was made to indicate what proportion of this increase is used in air conditioning. The fact that Reno has passed an ordinance restricting the discharge of air-conditioning water into the sewer system would indicate that probably a large percentage is so used. Reno has no meters because of a state statute which prohibits them in cities with over 5,000 population.

The Indiana General Assembly at its last session passed a law restricting the use of ground water for air conditioning. When more than 200 gpm. is consumed for this purpose, the water must be re-used or returned to the ground unless a permit is secured. Permits are to be denied in areas where records show that such withdrawal will be detrimental to the public health and welfare. The State Board of Health must approve recharge.

Pasadena, Calif., prohibits the discharge of waste water from air conditioning into the sewer system. This automatically compels the installation of conservation equipment.

The other side of the picture is presented by Phoenix, Ariz., which boasts that it has more air-conditioning installations than any other city in the United States. The water department considers itself obligated to encourage the use of water and air conditioning and does not believe that any restriction designed to curtail such use is justified, because the department is in the business of selling water and not of saving it. This attitude is supported by data showing the increased consumption over the past seventeen years and a statement that the water revenues have been adequate.

The results of the survey indicate that the problem is different in every community. What may be a reasonable regulation in one community may be burdensome and unnecessary in another.

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The extent of control necessary, or desirable, is an individual problem for each water supply, and is dependent on many factors. The quantitative and capacity aspects of the problem have been outlined by Frank C. Amsbury. (Control of the sanitary aspects is not

part of this discussion.) The most urgent topic is, of course, the matter of the quantity of water required and the capacity of the water works system to deliver that quantity. Statistics on the number of systems capable of fulfilling expanded demands may be derived from recently published surveys. It appears that 40 per cent of the water supplies of the larger cities should definitely have air-conditioning regulations in effect, though actually only about 10 per cent have any such rules or practice any volume control.

Condition of Water Supplies

In setting up any classification the limits must necessarily be somewhat arbitrary, but, taking into account the excesses of peak loads over the average, the author suggests that when use during the six months from May through October averages 90 per cent or more of the rated capacity of the water works, the condition should be considered critical. Likewise, when usage on the same basis exceeds 70 per cent, the time has arrived for a serious study of methods of limiting it.

According to these criteria, a recent survey (1) of 56 of the larger cities shows that 13 of the supplies should be considered critical and an additional 18 should study limitations. Only 25 of the systems can be classed as having a capacity which is adequate for more than the next few years, and only about one-half of this number have sufficient capacities to warrant actively encouraging increased water usage.

These facts would indicate that the water works systems of America may be divided into four approximately equal groups: (1) those which must be worrying daily about the adequacy of their supply, (2) those which should be studying or working for additional capacity, (3) those now enjoying safe balances of supply and demand and (4) those which should be encouraging sales to obtain increased revenue.

Quantities Used

In 1937 New York City calculated (2) a wastage for the summer season of 34 mgd., or 3 per cent of the total supply, by units which were not equipped with conservation devices. The amount of conserved use was not determined but was in addition to the 34-mgd. wastage.

In 1936 Chicago estimated the use of water for air conditioning in the central business district (the Loop) at 34 mgd. Assuming the rate of increase for this use to be the same as the rate for total demands in the Loop area, the total demand for air conditioning would have been 42 mgd. by 1945. Complete conditioning of the Loop area with unconserved units has been estimated to require 295 mgd.

Baltimore, Md., estimated that the use for air conditioning in the central city in 1947 reached 2,000,000 gph., which equals a rate of 48 mgd.

In Philadelphia for 1947, assuming that existing regulations are strictly complied with and, therefore, that all units over 30 hp. have conservation while none under 30 hp. are conserved, the use would have been 30 mgd., or approximately 7 per cent of the 439-mgd. maximum day's use in the system.

For the central area of Philadelphia, the use was calculated as 22 mgd., or 11 per cent of the total use in the area. It is the belief of the author that the use in Philadelphia is even greater than is indicated by these calculations (3) made for 1947.

Existing Regulations

In a round table (4) involving 36 water systems in 1945, only three noted any regulations, and these required only that all water for air conditioning must be metered.

A recent survey (1) indicated that, of 56 systems, only New York and Philadelphia have any official general restrictions on the amount of water use.

New York City's regulations have been described in a previous JOURNAL article (2). Briefly, metering is required where the minimum rate for operation exceeds $\frac{1}{2}$ gpm., and economizers where the use exceeds an annual average of 5 gpm. Separate metering may be required if the unit rating is over 25 tons, or the use exceeds 50 gpm.

The 5-gpm. average allowed without conservation equals 2.6 mil.gal. per year. Since the total demand-hours use is frequently calculated at 1,000 hours per year, then, under the New York City regulations, the use when operating may be about 6 cfm.; if the unit were operated only 600 hours per year the demand might be near 10 cfm. before conservation was required. In an actual installation consisting of a 40-ton and a 20-ton unit, only one of which was ordinarily operated at a time, the total use did not exceed the 5-gpm. annual average; no conservation was therefore required, yet this unit represented a peak load exceeding a daily rate of 170,000 gal. Because this flow would be ample for conserved units totaling more than 2,000 tons, it is evident that such a regulation accomplishes comparatively little, if anything, in the way of reducing peak loadings.

Philadelphia requires economizers where the maximum use exceeds 10 cfm. All new services must be metered, but separate metering of the water for refrigerative purposes is not required. This limit allows the operation of units of about 30 tons before conservation is obligatory. The amount of water needed for a 30-ton unit could serve an installation of over 750 tons, if properly conserved.

Detroit, Mich., Newark, N.J., New Orleans, La., Pittsburgh, Pa., and the District of Columbia grant permission for an installation only where the main capacities are sufficient. Wichita, Kan., excludes the discharge from sanitary sewers if the use exceeds 1 gpm.

Ten other systems are known to have considered regulations but have not enacted them. For three of these systems the May–October average was over 90 per cent of the rated capacity; for three others the percentage was 68–75; one each had a percentage of 63 and 40; and for two systems the percentage was unknown. Unless prospects for the expansion of supplies are developing, six of these systems should adopt regulations to control the demand.

Edmonton, Can., on the other hand, with a May–October average which is only 48 per cent of the capacity rating, indicates an extreme situation, as it is estimated that 30 per cent of the supply will be available for air conditioning for the next ten years.

Metering

No private utility would consider selling a product without a real measure of the quantity delivered, nor should a public utility. The metering of water should be required for all installations. This raises the question of separate metering for air-condition-

ing equipment. New York City *may* require a separate meter (2) on all units over 25 tons or 50-gpm. use, but the billing of water is based on the total used on the premises.

This method of billing leaves the customer paying for air-conditioning water on an increment basis. Separate billing would entail the minimum charges attached to such a service and would produce an added revenue. Would this amount be sufficient to cover the additional expense of metering, billing and miscellaneous costs attached to each service added to the listing, and also provide a surplus which might be considered as a partial return for the stand-by nature of the service?

Solely as a method of controlling the quantity of water used, the installation of a separate meter seems unnecessary. The horsepower or tonnage of the unit cán be used as the basis for regulations.

Each unit manufactured is equipped with a thermostatic valve which limits the water use to that amount necessary to remove heat from the unit. The condenser temperature setting is adjustable, however, and it is this setting which controls the amount of use. Neither the maximum rates of water use nor the amounts of water involved can be readily calculated for unconserved units. No practical basis for determining unconserved use can be obtained except by meter readings.

In each system, the means of billing to produce desired results should be worked out. The objectives will vary with the circumstances of the various systems. The aim may be to reduce water use or to derive only a reasonable profit from the service provided.

Flat Rates

Theoretical calculations from the water temperatures can be used to establish a water-use curve for operation throughout the year. The actual loading of the unit can be estimated from existing data, and from these results the annual use may be calculated. Rates can then be established. These must be set at very high levels, however, if the system is always to receive a reasonable return.

The use of flat rates where avoidable cannot be advised. Even on conserved units metering should be required, because flat rates on units equipped with economizers can be the cause of serious loss to the water works. For instance, suppose a 20-ton installation equipped with a water cooling unit was billed on the basis of the water which should be required (not more than 2.0 gpm.). If the recirculating equipment were shut down and tap water run through the unit, its capacity might be somewhat reduced from its rating. But, under flat rates, operators have no incentive to keep the adjustments set at the minimum water use consistent with satisfactory operation. Consequently, a saving would result to the customer, and a loss of 20,000 to 70,000 gpd. to the water works.

In New York City, regulations require metering, as previously mentioned, but for unmetered use a flat rate of \$30 per year per ton is established for unconserved units. For those conserved to below 15 per cent of unconserved demand, the rate is \$4.50.

Even a flat rate of \$30 per year per ton may not be sufficient if the water is not conserved. The possibilities of water waste are astonishing.

At Philadelphia water temperatures, the necessary water use, without conservation devices and assuming an average discharged cooling water temperature of 96°F., would average about 1.2 gpm. per ton from May to October. With a proper charge for water, the actual use would not average far above this. At a maximum-day supply water temperature of 85°F., the use would reach 2.7 gpm. If water is sold at a flat rate, the customer has no interest in economizing on its use, but he can save money on electricity. He will therefore set the condensing temperature at a lower point. Suppose he sets it at 96°F.; the discharged water temperature will be, say, 86°F. The temperature of the water in the supply rises to 75°, and the use will be about 2.7 gpm.; at 78°, the use will be 3.75 gpm.; at 82°, 7.5 gpm.; and at 85°, the required flow of water becomes 30 gpm. per ton, of which about 27 gpm., or 39,000 gpd., is unnecessarily wasted.

It can be seen that the only limit on the water actually used in many flat-rate, unconserved units would be the size of the service to the unit. If any flat rate is to be established it should probably be on the basis of service size.

New Regulations

The relationship between capacity and peak demands, the present high use for air conditioning and the probable rapid increase in refrigerative uses, seem to make it necessary for at least 40 per cent of this country's water systems to adopt regulations which will limit the demands and maximum usage and prevent waste. Because of the comparatively low water requirements of properly conserved units, there are few, if any, systems which need to restrict the tonnage installed.

Limits for the regulation of unconserved use should be set up on the basis of the maximum actual demand of units, or on their tonnage rating, and not on the average water use. This was demonstrated in the previous discussion of the existing New York City regulations.

In Philadelphia, studies have indicated that it is not usually economical to install units of over 10 or 15 tons without conservation. With increased water and sewer rates, the 10-ton limit will probably be the largest size generally economical. In many systems the much higher water rates indicate even smaller units. The size to be set as the top limit for unconserved installations should be determined by water works officials and should principally be based on the exigency of reducing demand, but consideration should also be given to the economic situation of the consumer.

Metering should be required for all installations but need not be separate.

The author does not believe that new or special schedules of rates should be established; existing rates should cover the situation for metered water. If additional revenue is needed, the entire rate schedule should receive an overhauling. It does not seem necessary to establish special higher rates for air-conditioning use than for other usage of like quantity. This statement is based on the belief that, although four large cities have indicated usage in excess of 30 mgd., this could be reduced to one-half by a 10-ton limit on unconserved units. With conservation there would probably be no more than a half-dozen installations in

a city which would use over 50 gpm. (equal to about 1,000 hp. in size).

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Although most water companies have not yet felt any real need for special rates or for regulations governing air conditioning, consideration and study should be given to this growing industry by water works men. One of the most important subjects to be discussed at this early stage of development is the question of water conservation requirements, which is always a good water works practice.

Water Sources and Requirements

The sources of cooling water include private supplies—both surface and underground—and water from city mains. Well water, if the quality is satisfactory and it can be obtained in the necessary quantities, is almost certain to be the best source of cooling water because of its constant cold temperature. Surface water—including rivers, lakes, ponds and streams—is the least commonly used source of condensing water because of the problems of quality, the presence of foreign matter and the depth of the water at extreme low-level conditions. The use of water from city mains requires the smallest investment for equipment and the least attention in operation. The cost of the water may be high, but, since less equipment is involved, expenditures for depreciation, maintenance and other fixed charges are low. According to air-conditioning and refrigeration manufacturers and representatives questioned by the author, over 90 per cent of the water-cooled installations are supplied through city mains.

The average cooling water requirements appear to be in the range of 1.5–3 gpm. per ton of refrigeration. One manufacturer estimates that 3 tons of refrigeration requires 4 gpm.; 5 tons, 6 gpm.; 10 tons, 12 gpm.; and 15 tons, 17 gpm.

TABLE 2

Refrigeration Equipment Sales, October–December, 1947

Equipment	Units Sold
Condensing units	9,805
Compressors and compressor units	5,490
Self-contained units	5,501
Total	20,796
Evaporative condensers (economizers)	1,131
Cooling towers and ponds	1,131
Total	2,262

Table 2 lists the results of a U.S. Bureau of Census survey of 72 manufacturers of air-conditioning and refrigeration equipment and accessories. These statistics apply to equipment actually billed and shipped in the fourth quarter of 1947 and are therefore equivalent to completed sales for that period. It is startling to note from Table 2 that over 90 per cent of the air-conditioning and refrigeration

equipment sold in the last three months of 1947 was without conservation. This same percentage holds good for the remainder of the year as well.

All of the many different types of condensing water systems in operation fall into two general classes: (1) those in which the water is passed through the condenser and then wasted to sewers or used for some other purpose; and (2) those using spray ponds or cooling towers, in which the water is recirculated, with make-up water added to balance evaporation losses.

Local Regulations

From the statistics on cooling water sources and economizers, it is evident that the conservation of water is the air-conditioning problem about which water works officials should be most concerned. A rule restricting the waste of water for air conditioning should be adopted by every water company, borough or municipality.

In a number of localities such restrictions are now in force. Chambersburg, Pa., prohibits the installation of air-conditioning equipment of 5 tons or more unless an economizer or cooling tower is installed. New York City limits the wastage of an air-conditioning system for a single consumer to an annual average of 5 gpm. Miami Beach, Fla., prohibits the connection of water waste from air-conditioning systems to sanitary sewers if the units in question use more than 2 gpm. of water. In 1944 the Virginia Section, A.W.W.A., passed a resolution recommending that no utility should supply water from the public distribution system for any new, additional or enlarged refrigeration at a rate in excess of 0.05 gpm. per ton of refrigeration.

Rates for water for air-conditioning use should come under the water company's regular rate schedule, and the author does not believe that any penalty rate is necessary at present.

Conclusion

The use of air conditioning in stores, offices, hotels, barbershops, beauty parlors and the like is rapidly increasing. It is being adopted by professional men, industries and even churches. Within the next five years home air conditioning with water-cooled equipment will become a significant factor, though residential installations today are practically all window models. Water works men should follow closely this growing demand on their systems and should be prepared with a policy to meet it.

Lynn B. Mighell

Carrier Corp., Philadelphia.

This discussion is primarily about the peak-load water requirements of summer air-conditioning installations. It is, therefore, concerned only with the cooling phase of a complete air-conditioning system.

If cold enough, water may be used to extract heat from the air by placing it in actual contact with the water—as in a spray-type washer—or by passing water through coils directly in the air stream. Because the economical use of this equipment is limited to those few areas where there is an abundant supply of water at a temperature usually not higher than 55°F. and because the number of installations employing water in this manner is small in comparison with those using other means, this paper will confine itself to air-conditioning systems utilizing refrig-

eration equipment. Such systems consist mainly of two parts: first, the air treating and distribution system; and second, the refrigeration system.

The most common type of refrigeration unit is the compression system which is made up essentially of an evaporator, compressor, condenser and receiver. In the compression system, the refrigerant absorbs heat from the air in the evaporator at a low temperature, and the compressor raises the pressure of the refrigerant to a higher level, discharging it into the condenser where the heat picked up in the evaporator is finally removed. This heat is carried away from the condenser by air or water or a combination of the two.

Condensers are classified, then, as air cooled, water cooled and evaporative. The air-cooled condenser consists of an extended surface coil through which air is blown by a fan usually attached to the compressor motor pulley. This condenser is not often employed on installations over 3 tons in capacity. It is used primarily on fractional tonnage jobs where water costs or temperatures are high, or where water supply and drainage facilities are not easily accessible.

Water-cooled condensers for air-conditioning installations are usually of the shell and tube type. Shell and coil type condensers and double-pipe condensers are rarely used on installations above 10 tons.

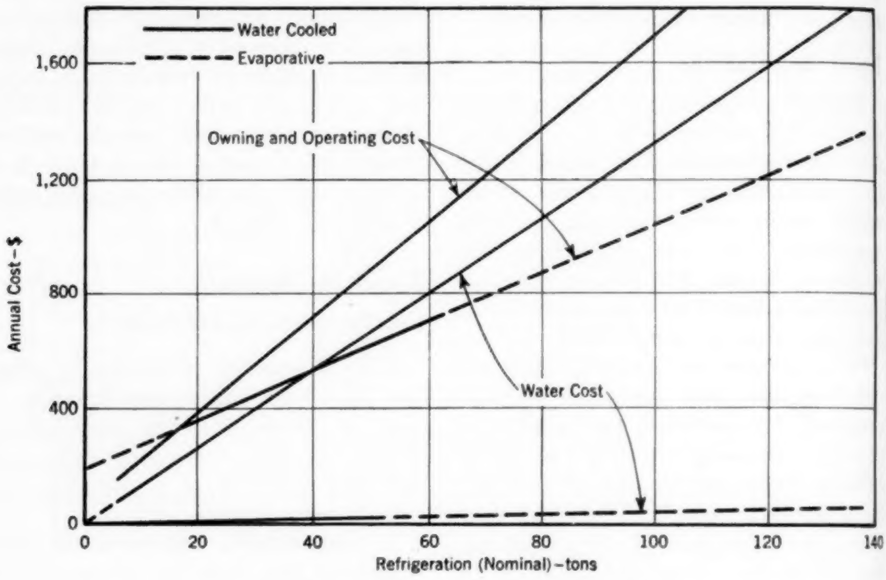

Fig. 1. Annual Cost of Refrigeration

Obviously, the simplest installation is one employing a water-cooled condenser in which water purchased from a public utility passes through the tubes and then directly to the sewer, the only change in the water being a rise in temperature. This type requires the least floor space and is lowest in initial cost. If this were the only way that the heat could be re-

moved, there would be good reason for graver concern about the condensing water demand. Fortunately, great reductions in the water requirements of air-conditioning systems can be effected by apparatus that permits the atmosphere to do the cooling.

ment applied to air-conditioning installations, when the high cost of water, or an inadequate supply, tended to restrict their use. The development of the cooling tower preceded air conditioning, and to make use of it no change was required in the design of

TABLE 3

*Recommended Condensing Temperature**

Entering Water Temp. °F.	Approx. Refrig. Suction Temp. °F.	Ratio of Water to Power Costs $\left(\frac{¢/1{,}000 \text{ cu.ft.}}{¢/\text{kwhr.}}\right)$					
		10	20	40	60	80	100
		Condensing Temp.—°F.					
60	0	82	82	82	90	90	98
	20	82	82	82	90	90	98
	40	82	82	90	90	98	98
65	0	82	82	90	90	98	98
	20	82	82	90	98	98	98
	40	82	90	90	98	98	105
70	0	82	90	90	98	98	105
	20	82	90	98	98	105	105
	40	90	90	98	98	105	105
75	0	90	90	98	105	105	112
	20	90	98	98	105	105	112
	40	90	98	98	105	112	112
80	0	90	98	105	105	112	112
	20	98	98	105	112	112	112
	40	98	98	105	112	112	112
85	0	98	105	105	112	112	112
	20	98	105	112	112	112	112
	40	98	105	112	112	112	112
90	0	105	105	112	112	112	112
	20	105	112	112	112	112	112
	40	105	112	112	112	112	112

* Maximum temperature of water leaving condenser averages approximately 10° below condensing temperature.

Equipment in common use includes natural- and mechanical-draft cooling towers, spray ponds and evaporative condensers. The cooling tower was the first water conservation instrument applied to air-conditioning installations, when the high cost of water, or an inadequate supply, tended to restrict their use.

the refrigeration system. By cooling the warm water from the condenser by direct contact with air in the cooling tower, and then re-using the water by pumping it through the condenser, the

consumption is reduced to about 5 per cent of what it would otherwise be.

The second step in water conservation on air-conditioning systems was the development of the evaporative condenser, which combined the functions of the water-cooled type and the cooling tower. The evaporative condenser utilizes the principle of evaporative cooling, as does the cooling tower, but instead of cooling water that condenses the refrigerant in a shell and tube condenser, it condenses the refrigerant directly, resulting in a lower condensing temperature. It is a complete condensing unit which replaces the cooling tower, the water-cooled condenser and the water circulating system.

The evaporative condenser is essentially an air-cooled condenser consisting of a coil in which the refrigerant gas is condensed by the evaporative cooling effect of water sprayed over the outside of the coil. Fans draw the air over the coils and through the sprays. Since the rate of evaporation is related to the wet bulb temperature of the air, the capacity of the condenser also depends upon the wet bulb temperature. Compared with the cooling tower and the water-cooled condenser, the evaporative condenser takes up less space and is lower in first cost. Because there is no windage loss from the evaporative condenser, the water make-up is slightly less than with the cooling tower.

There are many variables that enter into the selection of an economical condensing system. These factors include: (1) water and sewage rates, (2) power costs, (3) water temperature, (4) outdoor wet bulb temperatures, (5) initial costs of the various types of condensing equipment and (6) availability of water supply and pressure.

Conditions in one locality are generally not the same as those found in another, nor does a set of figures prepared for a restaurant operating 24 hours a day hold for a suite of offices in the same building that are in use only eight hours a day. As a result, it is usually necessary to study each type of installation as a separate problem, even where the water supply is adequate and restrictions are nonexistent.

An investigation of the conditions in Philadelphia was made in order to determine at what point it would pay an owner to invest in water conservation equipment, instead of using city water. Figure 1 shows the results in the form of a graph. The bases for the computations were: (1) first cost of condensing equipment as of December 1947; (2) fixed charges calculated from the formula:

$$C = \frac{100}{y} + \frac{y+1}{y} I$$

in which C represents the fixed charges, y the depreciation period (taken as 10 years) and I the annual interest rate (taken as 5 per cent); (3) operating time, 1,150 hours a year for power and 820 hours a year for water required for condensing, representing the equivalent full-load refrigeration operating hours; (4) cost of electricity, 1¢ per kilowatt-hour; (5) cost of water, 68¢ per 1,000 cu.ft. (including a sewage tax of 28¢ per 1,000 cu.ft.).

Examination of Fig. 1 indicates that for the specified conditions the owning and operating costs of systems under 15 tons are lower for a water-cooled than for an evaporative condenser.

This balance point of 15 tons may vary somewhat when costs differ from the basic ones used. Furthermore, increasing the water rates by as much as 50 per cent will only decrease the balance point slightly.

The capacity of a water-cooled condenser depends on the condensing temperature, the temperature and quantity of the water, and the refrigerant suction temperature. Condensing temperatures are sometimes determined by the ratio between water and power costs (cents per 1,000 cu.ft. to cents per kilowatt-hour), as shown in Table 3. This method of selection takes into consideration only operating costs, and frequently the relation between initial and operating costs makes it necessary to modify such choices.

The accepted practice is to employ the formula $QT = 30$, in which Q is the quantity of water in gallons per minute per ton of refrigeration load and T is the rise in the temperature of the water in the condenser—for example, 3 gpm. per ton with a 10°F. rise, or 2 gpm. with a 15° rise. There should be a spread of 5°–10° between the condensing temperature and the temperature of the water leaving the condenser. These are approximate values and varying job conditions govern deviations from them.

Data used ten or fifteen years ago to select the most economical equipment, cannot, as a rule, be used with accuracy today. Power rates have been gradually coming down and the cost of water, as well as of equipment, has been going up. The change in utility costs has resulted in a general tendency to operate refrigeration systems at higher condensing temperatures. As a consequence, more electrical power and less water are required per ton of refrigeration. This is a healthy trend but should be supplemented by increased effort to encourage the use of water conservation equipment where the water supply system is in danger of being overtaxed.

The whole problem of water usage is, of course, affected by local conditions. Communities differ so widely in the number of air-conditioning installations and in their water supply that few generalizations would apply to all. Local surveys are therefore the most dependable method of finding a solution.

Marsden C. Smith

Chief Engr., Dept. of Public Utilities, Richmond, Va.

There can be no doubt that water required for air-conditioning equipment presents a serious problem if it is to be supplied by the public water systems. But there are other demands that also create serious problems. Lawn sprinkling, swimming pools and similar seasonal uses of water are in exactly the same class and intensify the problem of hot weather peak demands just as does air conditioning. Therefore, in spite of the fact that the subject assigned to this panel is water use by air-conditioning equipment, it seems proper to extend the discussion to cover any use of water which creates an unreasonable demand.

Before attempting to determine the most successful means of solving the problems created by unreasonable demands, it should be ascertained that any proposed solution is both legal and reasonable. This is not only common sense but is necessary because there are some water utilities which are privately owned and others which are

publicly owned. For this reason, a solution which may be approved by a city council for a municipal system may not be at all acceptable to a state commerce commission.

It should also be realized that the peaks due to seasonal demands do not cause equally serious problems throughout the limits of the area served by the A.W.W.A. In tropical climates the seasonal peak is lessened, or at least there is a far greater gross revenue obtained from hot weather sales than in those areas which have a short but intense hot weather period. And it is well to remember that the North American opposes specific high rates or any special regulations. He demands, and usually gets, pretty much what he wants, unless he can be convinced that he is not being treated unreasonably. He will claim discrimination just as quickly against a high special charge for service as he will against a denial of, or a regulation of, the conditions of service.

If, for example, the water purveyor attempts to limit the water used for air-conditioning equipment by specific rates, the customer may claim, with much justification, that lawn sprinkling creates an equally severe and unreasonable demand. Then, if the purveyor is to escape this charge of discrimination, he will have to accept the serious complications in metering, billing and accounting that must be incurred because of the special rates necessary for each of the seasonal peak demands.

On the other hand, the customer will undoubtedly register an effective complaint if he should be denied the use of water for air-conditioning equipment and at the same time see his neighbor continue lawn sprinkling, using a swimming pool or some other equally nonessential seasonal utilization of water. This would most certainly constitute flagrant discrimination.

Compromise Solutions

The author is therefore strongly opposed to any limitation on the use of water that can be avoided without serious consequences. Several instances may be mentioned of unreasonable demands which have been checked by an appeal to reason, and in none of these have specific rates been required to protect the system. Indeed, it is probable that had the effort been made to cover the higher expense of certain of these services by specific rates, the increased cost of the resulting complications would have largely cancelled the increased revenue obtainable.

The first of these unreasonable demands occurred when the owner of a large estate applied for water service to supply several hundred lawn sprinklers. To permit all of these sprinkler heads to be operated simultaneously would have required a major enlargement of the water distribution system, useful for only a few hours each year. The solution of this problem was to limit—not deny—the demand; this meant operating the sprinklers by sections rather than all at the same time. The solution was accepted by the customer as a reasonable regulation.

A different problem was created by the request of a railroad for a 4-in. connection to be used only for quickly filling diesel locomotive tanks. Such sudden variations in demand would have caused serious pressure fluctuations and adversely affected other consumers. The total volume was much

too small to justify the cost of an enlargement of the distribution system. The solution adopted was to permit a service limited to a 90-gpm. rate to fill a tank erected at the customer's expense on his property. The railroad was entirely convinced that this solution was quite reasonable and fair.

A very different situation involved a swimming pool where proper sanitation required the use of as much as 1 mgd. when operating at the maximum attendance permitted. Naturally, the full use was limited to a few days a year, which exactly coincided with the days on which all other demands were at a maximum. The solution here was not to order the service discontinued but to limit the quantity of water to that necessary for make-up. The operator at first refused to install a circulating purification system but eventually gave in. In fact, he later actually requested a rebate to cover the losses he had been permitted to suffer before being forced to economize. If no special rate is charged for a bath at home on a hot day, it does not seem equitable to charge extra for a swim in a public tub.

Another variant of the problem is that of private fire protection. This is solved in one city by an ordinance providing that if the requirement for water for private fire protection necessitates the enlargement of the public distribution system, which, in the opinion of the manager, gives public protection equal to or better than the average for similar districts within the city, the entire cost of the new or enlarged system shall be paid by the beneficiary of the private fire protection. No charge is made for water used for fire protection, either from a city-owned fire plug or from a private system.

Still another problem was solved without the use of special rates or regulations. A water department was severely criticized for being unwilling to supply an unestablished manufacturer with more water than the entire city of 235,000 population normally used. Here the solution was one that had been fully established by other utilities. The city offered to supply the requirements, provided that the manufacturer would deposit with the city an amount equal to the cost of the system enlargements made necessary by his demand. The deposit would be repaid to the manufacturer at a fixed per cent of the gross charge for water at standard rates. No discrimination could possibly be claimed, because this is merely the same deposit required of all new customers, proportional to the risk involved.

These examples all indicate that specific rates are rarely necessary, certainly not when a reasonable solution can be obtained otherwise. They also show that water systems cannot escape the seasonal peak demands any more than can other utilities. But water works may properly use any reasonable means to reduce the severity of unusual or unreasonable demands.

Reasonable Reductions in Demand

To return to the subject of water required for air-conditioning equipment, the same principle clearly applies here as in the problems just described: a reasonable reduction in the intensity of the demand should be made, but there should be no denial of use nor any special rates, unless absolutely necessary.

Fortunately for everyone, water economizers are almost a necessity for large air-conditioning units, even when

standard rates are charged for the water used. This fact tremendously reduces the seriousness of the problem.

For the smaller units, not now generally obtainable with economizers, it is quite probable that economizers or air-cooled units will be made available if the charges for water are sufficiently great to justify the added cost of such equipment.

For the immediate present, however, and until the magnitude of the problem is definitely established, it seems quite reasonable to require economizers for, say, individual units larger than 5 tons. Economizers would also be required for those units of 5 tons or less placed in a single building containing a total of more than a 5-ton rated capacity. All water would be supplied at standard rates.

After these regulations have been in effect for a reasonable time, and if in spite of them the demand is still found to create a problem, then further action can be taken. From experience thus obtained the necessity for far more drastic action can be demonstrated by facts rather than by anticipation. As a result, specific high rates may then be charged with full justification.

To sum up, it appears that a reasonable solution can be found for almost every problem without the complications of special rates or discriminatory regulations. But when special rates can be shown to be definitely necessary for the protection of the utility, they must be made sufficiently high to cover not only the cost of water service, but also the added expense of applying the special rates.

Reservoir Lands Pay Their Way

By Wendell R. LaDue, George F. Hughes and John M. Heilman

A panel discussion presented on May 6, 1948, at the Annual Conference, Atlantic City, N.J., by Wendell R. LaDue, Supt. and Chief Engr., Bureau of Water and Sewerage, Akron, Ohio; George F. Hughes, Exec. Secy., Denver Board of Water Commissioners, Denver, Colo.; and John M. Heilman, Forester, Newark Div. of Water, Newfoundland, N.J.

Balanced Use of Reservoir Lands—*Wendell R. LaDue*

THE Akron, Ohio, water works embarked upon its career as an owner and developer of surplus lands in 1915, when its new water supply was placed in operation. The impounding reservoir, Lake Rockwell, with a water surface of 750 acres, had a protective surrounding excess land area of 1,750 acres. In 1922 the purchase of an additional protective area of 50 acres, planted mostly in fruit, involved the city in the fruit business. Subsequent plantings enlarged the orchard and vineyard to 190 acres. As much as 30,000 bushels have been harvested in one fall. At first the department operated the fruit business in all its details, but later this procedure was abandoned in favor of a rental contract agreement with a competent horticulturist. It was believed that the utility should not engage in a business so competitive in this area. The present plan is to continue leasing the land until the orchards prove too old for profitable operation. No trees are being replaced and vacated areas are being covered by grass or reforested.

Afforestation at Lake Rockwell, started in 1922, has been continued throughout the years until there are now approximately 800,000 trees, both conifer and deciduous, in close planting on 950 acres. The practice is to purchase two-year seedlings, plant them in nurseries and after two or three years transplant them permanently. Spring planting, with losses under 5 per cent, has been found more satisfactory than fall planting. The remaining acreage is in grass and natural woodland.

The new forests have afforded excellent game cover. Last year as many as twenty deer in one herd were observed by patrolmen. Several beaver houses have been built in a low spot bordering the impounding reservoir. An ample food supply of aspen is available.

The closed reservoir itself affords a welcome stopover for ducks and geese. In cooperation with the Ohio Conservation Commission, each year approximately 100,000 mature breeder fish are removed by seining the closed reservoir. These fish are distributed by agreement to open lakes in Ohio, 70 per cent going to 35 lakes in Akron's home county of Summit.

The Akron Water Bureau has worked very closely with the various Ohio state agencies interested in the conservation and proper development of

the state's natural resources. The public relations value of this procedure is apparent.

The foregoing has dealt with the protective land holdings about the Lake Rockwell domestic impounding reservoir, an area which is closed and patrolled because this reservoir is directly connected to the treatment plant.

Balanced Use Program

Early in the 1920's it became evident that additional storage would be required for the Akron water supply. A survey was made and a potential reservoir site on the same watershed was found approximately twenty miles above Lake Rockwell. Throughout the years about 8,000 acres has been acquired. In 1937 about 500 acres was flooded by the construction of a second impounding reservoir. In this 8,000-acre area a balanced program of farming, cattle and sheep raising, maple syrup production and forestry is being carried out. The area is roughly divided as shown in Table 1.

TABLE 1

Reservoir Land Use

Purpose	Area *acres*	Area %
Reservoir water surface and shoreline protection	1,500	19
Maple sugar bushes	600	8
Farm land (leased to 64 farmers)	2,600	32
Pasture for sheep and cattle and farm land for feed, etc.	1,200	15
Forests and wood lots (other than maple bushes), swamp areas	2,100	26
Total	8,000	100

The major activities of the city in this area are cattle and sheep raising and the growing of feed. In the early years of the 1930 depression about $150,000 was expended in clearing over 2,000 acres of future reservoir bottom area. This supplied jobs for the needy of Akron. To prevent the land from again going wild and thereby causing the investment to be lost, it was decided to build up a herd of cattle, later supplemented by a flock of sheep. The cattle are the Domino strain of the Hereford breed, which is noted for its beef qualities, its hardiness and sturdiness. For obvious labor reasons, dairying was not undertaken. The animals are handled entirely as range cattle and, when winters are mild, forage the year round. Of course, existing barns are used for winter feeding. The herd is reduced each fall to about 300 head by culling and selling the increase.

TABLE 2

Average Annual Reservoir Land Income

Income	
Maple Syrup, 285 gal.	$ 1,100
Lumber, 33,000 fbm.	2,300
Wool, 5,700 lb.	2,200
Sheep, 800 head	400
Cattle, 300 head	8,500
Farm land rental	5,500
Other sources	1,400
Total	$21,400
Operating Expense (average)	$19,300

A flock of about 800 Delaine Merino sheep is maintained by fall culling. The sale of 5,700 lb. of wool annually is an important source of revenue.

The feed grain for the cattle and sheep is grown on reservoir land, and no food is bought. In years of surplus, the excess is sold but no commercial farming is undertaken. In a peak year 16,000 bales of hay have been stored.

Some lumbering of the wooded areas below the proposed flow lines of the

future reservoir has been done. Reforestation is practiced in cut areas above the flow line. The lumber is used for the usual water department functions and as firewood for maple syrup production. No rough lumber has been purchased by the department for many years.

The reservoir land is in the maple sugar district of Ohio, one of the best in the country. Over 300 acres of bushes now have a capacity of 5,000 buckets. At present only 3,000 buckets are being operated, and a maximum of 620 gal. of maple syrup has been produced in one season. Potential bushes totalling a like capacity may be developed if the demand warrants. The syrup is sold locally in 1-gal. cans and the demand always exceeds the supply. Fortunately, most of these woods are above future reservoir waters.

As previously noted, approximately 2,600 acres of land is tenant-farmed by 64 farmers. As part of their agreements, the farmers are prohibited from converting sod lands into plowed land and modern farming methods are required.

Trapping rights are leased annually and controlled hunting is permitted. A nominal fee of 50¢ per hunter-day is charged. The permit is good only for the day purchased and the hunters are allotted certain areas where they may hunt unmolested by others. An average of 330 permits is issued each season.

A financial summary of this balanced use of the 8,000-acre area is presented in Table 2, which gives the average annual income over the ten-year period from 1938 to 1947.

It should be remembered that the operating surplus does not reflect the greater profit derived from protecting the $150,000 investment in the cleared area.

Mogadore Reservoir Lands

During the WPA era it was deemed advisable to construct, as part of the city's WPA program, a reservoir to better the raw water supply for the industries of Akron and to afford additional recreational facilities for Akron and suburban citizens. Since it was a water project, its construction and operation was placed under the supervision of the Akron Bureau of Water and Sewerage. Approximately 2,500 acres was acquired by outright purchase. The present reservoir (known as the Mogadore Reservoir) has a water surface area of 1,000 acres. About 800 acres of the remaining land has been planted with 465,000 pine and deciduous trees.

TABLE 3

Fishing Preserve Operation

Item	Annual Average
Days open for fishing *	92
Number of fisherman-days	14,000 †
Number of boat-days	4,626
Fish caught	73,000 †
Income	$3,754
Operating expense	$2,514

* Approximately from July 1 to October 1.
† Estimated.

Because this area has been planned for ultimate recreational use, drives and tree planting areas were laid out with that end in view. War and postwar labor conditions have retarded the construction of recreational features, but a portion of the reservoir has been opened for fishing under rigid departmental control in which the State Dept. of Conservation joins.

The reservoir was filled in 1939 and stocked with bluegills, crappies, bass

and perch from Akron's Lake Rockwell by the State Conservation Commission, at the rate of about 8,000 to 10,000 mature fish per year for four years.

By 1943 fish counts by this agency indicated that the reservoir was ripe for fishing; therefore, as an aid to relaxation for the many war workers in Akron, a 350-acre portion of the reservoir was opened to public fishing under rigid wartime restrictions concerning location, to avoid the possibility of sabotage. Sanitary conveniences, tested wells and boats have been provided. Before opening the reservoir, the regulations were reviewed and approved by the officers of seventeen sportsmen's groups representing over 15,000 members. This step was taken to further public relations. Although wartime restrictions are now unnecessary, they have been maintained and the public seems satisfied.

The average annual operation statistics for the five-year period, 1943–47, are summarized in Table 3.

The income is from the rental of boats only. No charge is made for shore fishing. Some border land is leased for farming but this is a very small item, most of the land being held for park and recreational purposes.

In the spring of 1948 a very successful experiment was made in opening the reservoir for crappie fishing only, from April 1 to April 25, inclusive. The cooperation of sportsmen was gratifying and spontaneous, again through the sportsmen's groups.

Because the reservoir lands were not purchased primarily for farming or recreational purposes, the items of taxes, interest and bond retirement should not be debited against the income obtained from attempts to use the lands profitably. The projects are therefore considered self-supporting; they afford a means of maintaining the unused property in good condition and are conducive to better public relations, not only in the immediate locality of the property but throughout the city and its environs.

For those desiring it, a more detailed account of the Akron program can be found in an article by the author published several years ago (1).

Reference

1. LaDue, Wendell R. Problems of a Municipal Water Works Land Owner. Wtr. & Sew. Wks., **92**:181, 209 (June-July 1945).

Income From Water Department Property—*George F. Hughes*

THE plains of Colorado lie in what is termed an arid belt, and consequently all the water available from mountain streams is in great demand for domestic use by the cities and towns of Colorado, as well as for irrigating farm lands. The city of Denver, therefore, in addition to securing the direct flow of water from streams under decreed water rights, has constructed large reservoirs to impound the flood waters that occur in mountain streams in the spring of the year. Denver has also been obliged to purchase farm lands in order to acquire additional water rights attached to such lands.

All decreed water rights throughout the state are under the jurisdiction of the Colorado State Engineer, whose office supervises the allocation of water from the streams in the several districts. Water rights are a valuable asset and are preserved with great

care. An old saying in this section of the country is that you may elope with a man's wife or steal his horse but do not use his water rights or a tragedy will result. There are two kinds of water rights—reservoir rights and direct stream rights—which are allocated to owners according to the date of the decree by Colorado courts. Both of these rights are very valuable if they have an early decree date.

With this background, it is readily understandable why Denver has purchased farm lands having valuable water rights attached to them. For example, in 1931 the Denver Water Dept. purchased a ranch of 1,100 acres for $100,000, which included water rights valued at $55,000, so that the department could have use of the water and also control the operation of the ditch company.

To secure property for the location of a reservoir, the Water Dept. purchased another 500 acres with certain water rights attached, for $40,000; a provision in the contract stating that the former owners would have perpetual use of the surface land was, of course, a factor in determining the purchase price.

Another piece of property, purchased because a portion of it was required for a reservoir site, was a summer resort on which fourteen cabins and a store building were located. This resort is being rented to a caretaker for $300 a year, with the provision that he pay all the operating expenses and keep the buildings in repair. The department wants to retain these cabins, as housing will be necessary for employees who will work on the large dam to be constructed in the vicinity sometime in the future.

From a 20-acre tract of land, formerly used for a conduit right-of-way and now abandoned, the Water Dept. receives 10¢ per yard royalty for sand and gravel, with a minimum annual payment of $4,000. This property is within the city limits, and it is estimated that a total revenue of approximately $90,000 will be received over a period of twenty years. After the sand and gravel are removed the Park Dept. of Denver desires to use the property for park purposes, as seepage will fill the excavation with fresh water, creating a lake.

Another unusual use of Water Dept. land is the operation of a flour and feed mill, which is leased for $900 a year. The mill was acquired at the time the city took over the water plant from a private corporation in 1918, and it is necessary to continue the operation of the mill with water power to protect valuable water rights.

Other land owned by the department is occupied by a filling station, the lessee being required to keep up the improvements on the property and pay the department $600 annually.

Farm lands acquired by the Water Dept. having valuable water rights are retained and leased to tenants on a sharecropping basis and a rental is stipulated for any grazing land. Ownership of farm land so acquired is retained by the department, as it has been found from experience that if the land is sold the new owners are generally able to obtain water by purchasing it from some other user who has more than is needed for his own property. This results in a larger demand for water; otherwise, when users have a surplus amount of water it remains in the streams as an additional supply for the regular users.

It is not the purpose of the Water Dept. to retain property that is unnecessary for the operation of the plant;

consequently, all such property is advertised and sold to the highest bidder, putting it back on the tax rolls.

All land surrounding reservoirs is leased for the grazing of stock or for the raising of crops. The large reservoirs are located at high elevations where the growing season is short, and the excess lands surrounding these reservoirs are therefore available only for grazing purposes.

Records of revenue from leases of Water Dept. farms and excess lands surrounding reservoirs show a fair return on the principal invested. For example, the income received from crops and grazing rental on the 1,100-acre ranch for 1947 was $9,960.95, while from all lands owned by the department the amount of $19,319.24 was received, in addition to revenue from the gravel pit.

Forestry on Reservoir Lands—*John M. Heilman*

The author is forester on the Newark, N.J., watershed of 41,000 acres, of which approximately 35,000 are municipally owned. It is his conviction that watershed forestry can be made profitable. In fact, it has paid its way on the Newark watershed for the past several years.

The two statements made above are based upon the premise that the land is purchased for watershed protection with forestry as an incidental use. Before buying the land, any private or municipal water company will, of course, explore the various sources of water supply—spring or well water, filtered or unfiltered surface water—and will also make a study of consumption needs, production costs and the like. It is assumed that these studies have led to a decision that the best results can be obtained by purchasing the watershed land and delivering unfiltered water to the consumer. The management, therefore, has in its possession land bought for purposes of water supply, and obviously the taxes on this land will be charged against the water and not against the forest growth.

The incidental income which may be obtained without impairment of the water supply will naturally vary with each watershed and is dependent on a number of factors, such as proximity to markets, the type of product in demand, the type of vegetative cover and the growth rate.

Newark's watershed has two outstanding general characteristics—the first a liability, the second an asset. The unfavorable characteristic is a thin soil natural to the New Jersey highlands. The valley lands are either in man-made reservoirs or consist of abandoned farms or grazing lands which are slowly reverting to forest. It will be many years before the better valley soils produce a major income.

The favorable characteristic is proximity to markets. The drainage area lies within 50 miles of a population of perhaps 10,000,000 people: the residents of New York, Newark, Jersey City and many smaller cities and towns, chiefly to the east and southeast.

Newark's Disadvantages

In attempting to profit from its watershed forest area, Newark suffers from four disadvantages:

1. The infertile condition of the soil results in a slower rate of growth than in more favorably situated areas to the south. As a result, large timber op-

erators are generally more interested in the higher-quality stumpage obtained in other parts of the state where the absence of rocky topography makes logging cheaper. Water Dept. timber sales, therefore, return a comparatively low price per 1,000 fbm. of stumpage and usually only the smaller operators are interested.

2. Approximately 22 per cent of the land is in ridge-type chestnut oak, the growth of which stagnates at about 40 years of age. Its size is too small for any current use except as cordwood or a similar product. Some of this type grows on steep slopes that will be retained as protection areas and the trees will never be cut down.

3. A municipality works under different labor conditions from a private corporation, a fact which tends to increase the costs of production. Newark labor is under Civil Service regulations, and, though the rates of pay per hour are lower than those of private corporations, there are more paid holidays and the men are employed all year round, whereas a private corporation would use only a few key men during "off" seasons and hire seasonal employees during the high-production months. Private concerns generally release an over-age man or put him in a lower pay bracket, which is not done in municipal employment.

4. A municipality works under very strict sales regulations. Forest areas of low sale value attract only the small operator, but the complicated procedures the purchaser must go through and the long wait for the sale to be approved generally frighten the small operator, so that he either bids low or not at all. Then, too, the technique of mapping and cruising and the necessity for public advertising often cost the city more than the returns of the sale will justify and no sale is made. These conditions are common to practically all cities.

Newark's Advantages

Proximity to markets permits the sale of certain products that could not be marketed elsewhere. A few such items may be listed:

Christmas trees. Despite the fact that the balsam fir, which is out of Newark's natural range, is a general favorite in the section, the Norway spruce and red pine of the department's plantations are becoming increasingly popular as Christmas trees. Many people like the greater quantity of green branches on the spruce as compared to the fir, and in the immediate vicinity of the watershed the red pine is preferred because it retains its needles longer. Close to $10,000 worth of spruce was sold in a few weeks prior to Christmas in 1943, which indicates that an annual market could be developed, though of somewhat smaller proportions. In making the spruce sales the only costs to the department were for providing a man to point out which trees could be cut in thinning operations and for cruising and mapping for advertising purposes the areas which were clear-cut and replanted the following year. The average price for such trees has been about 40¢ each on the stump. Larger trees have been sold at $1.00 per linear foot on the stump.

Boughs. Red pine, white pine and Norway spruce boughs have been sold for Christmas door and funeral wreaths, generally at $10.00 per ton on the tree. The method used has been to allot each purchaser a planted field and require him to use pruning shears or saw and cut flush with the main stem.

Products for mines. To the immediate north, south and west of Newark there are iron and zinc mines. The New Jersey Zinc Co. owns land adjacent to the watershed which was bought primarily for mine timber production. Some of the products that have been made from watershed timber are posts, props, lagging, railroad ties and even blasting poles. A blasting pole is about 10 ft. long and 2 in. in diameter at the small end, and has sold for 5¢ each on the stump. This sort of material is generally left as unusable brush in a logging operation.

Larger timber. Larger timber has gone into general construction. Squared timbers, up to 12 × 12 × 30 ft., and piling have come from the bulk of the largest and straightest trees, but rough lumber for general construction purposes constitutes the greatest volume produced. There is no real problem in marketing the better timber.

TABLE 4

Topography of Newark Watershed

Physical Feature	Area * *per cent*
Water surface	5
Swamp land	3
Old fields	30
Planted fields	7
Ridge forest	22
Slope forest	25
Cove forest	8

* Total area 64 square miles.

Income From Forests

Newark's policy on watershed forests was outlined at a meeting of the New Jersey Section, A.W.W.A., two years ago, when it was stated:

> The forest policy on the watershed begins with the simple principle that the land is being held for water supply needs, not forestry practice. Forest expenditures, like all watershed costs of whatever description, are chargeable to obtaining a potable water supply. It follows, therefore, that no forest work may be done that will be detrimental to the water supply and that net forest income is purely secondary to the primary object of water production. On the other hand, it is recognized that a forest in its natural state may often furnish the same ideal conditions for water purification as a well-managed stand, so that no money is expended for forest practice unless it is established that such practice will pay for itself.

This policy has kept forest expenditures at a minimum and forest income at a point that does little more than pay the expense of administration. Only dead, burned, diseased and overmature timber has been sold to date, except for spruce trees and the like, as previously outlined.

Newark's 64 square miles of watershed can be classified as shown in Table 4. The slope and cove forests will be the first sources of major income and will begin to show a marked increase in about twenty years. The present watershed inventory is approximately 235,000 cords of wood and 12,000,000 fbm. of timber. Almost half of the cordwood is in young stands of future saw timber and most of the present saw timber is at the stage of rapid volume production, so that it would be decidedly unwise to cut it at present. The forest must be considered as a long-term crop. The farmer could sell his hay when it was half grown, but he would realize only half the money he obtains by waiting for full growth a few weeks later. Similarly, once full growth is attained the hay must be cut or it becomes worthless. So it is with timber. Newark's timber is in great part immature. Prior to purchase by the city, most of the forest

land was cut over. New stands have become established, however, and these are now producing at a fairly rapid rate. As they mature they will be harvested in accordance with sound forestry practice, which will increase the rate of growth on the residual trees and shorten the intervals between successive cuts. It is estimated that in twenty years a sustained yield of about 1,500,000 fbm. can be cut annually. Under good forest management this yield can be materially increased in 50 years, with from 3,000 to 5,000 cords of wood available annually from the tops and poorer areas.

The expenses of forestry work today, including the forester's salary, are approximately $6,000 yearly—actually considerably less since much of the forester's time is devoted to other work. The average income over the past few years just about balances this figure. It is estimated that the income in twenty years will have increased sixfold or to about $35,000, while the costs of operation, marking, supervision and so forth will not exceed $18,000, giving the city a net income of approximately $17,000 per year. This will be a very significant contribution to the tax load on the watershed land, from a source of "secondary consideration." Moreover, because of the methods of harvesting this "secondary" source, there can be no unfavorable effect on the water-holding capacity of the watershed.

When it is considered that the sale of Newark's water returns about $3,000,000 a year, it may not seem worth while to bother with an insignificant $17,000 net income which will not be reached until twenty years hence. But the forest practice is maintaining and improving the water supply and it will be returning a very sizable percentage of income over and above the costs of operation. Furthermore, the knowledge that the cutting is being done properly—with the growth and inventory in an area known before and after cutting and only one-eighth to one-third of a stand being removed in a single operation—will give the public a feeling of confidence in the management.

Business today does not generally expect a yearly return of 10 per cent over a long period of operation, nor does it expect every branch of its operations to produce a large return. It does recognize that it may pay to have a small return or even suffer a loss from some operations to perpetuate a larger return from the main one. In the lumber industry, for example, the practice thirty years ago was to "cut out and get out," salvaging what was possible from the mill and letting the land revert to the county for taxes. There were few foresters employed and these were generally used for surveying, timber estimating and the like, with no attention being paid to perpetuating the forest. Today some of the large companies have a hundred foresters on the payroll and many are cutting on sustained yield. It is now known to be better to practice one of the systems of partial cutting and obtain good natural regeneration, for by obtaining a 1–3 per cent growth in the forest inventory a 6 per cent or greater profit can be maintained in the milling operations.

It is the sincere belief of the author that many water companies owning forest land might find it profitable to employ a trained forester. There have been numerous instances in the past of timber sales improperly made or labor time ill spent because of a lack of certain fundamental knowledge. A

few examples will suffice to illustrate the point:

In New Jersey fallen timber is generally scaled by the Doyle rule, which is meant to apply at the small end of a short log. The overrun is tremendous on a long log of small diameter, and the logger, knowing this, generally removes the full length of the tree as one log. A 40-ft. log 8 in. in diameter at the top scales 40 fbm. Newark once sold logs on this basis, which was, of course, standard practice. Today the buyer is required to pay the scale with the diameter taken at mid-length, which gives a scale of about 150 fbm. for the same tree.

The author has seen surveyors stake out fields at 6-ft. intervals so that planted trees would set in straight rows. By this practice the cost of planting is magnified about tenfold, and after a few years the tree crowns close and no one can tell the difference.

It was once strongly recommended by a non-forester that all the apple and cherry trees over the entire watershed area of 64 square miles be cut down to eliminate the tent caterpillar. This would have been almost as costly as hard-surfacing all the dirt roads and less practical. Within two years nature's cycle had brought the caterpillar under control, and though the insect was unsightly when present it did no lasting harm.

Summary

The primary object of Newark's forest management is to retain and improve the quality and quantity of the water supply. Income is very much a secondary objective. The volume of salable timber today is low because of the condition of the land at the time of purchase. In twenty years the oldest of the present young stands will reach marketable saw-timber size, and forestry from then on will pay handsome profits over the costs of administration, provided that good cutting practices are followed. Because Newark is operating under municipal labor and sales regulations, the city will probably not obtain as much net income as a private corporation doing its own logging and milling. It is possible, however, with a minimum of overhead, to sell on the stump and realize a good return, building up the rate of growth with each cutting until the maximum is reached, and avoiding, by proper management and restrictions, erosion and other conditions that might adversely affect the water supply.

Chlorine Supply and Demand

By J. O. Logan

A paper presented on Nov. 21, 1947, at the Four States Section Meeting, Washington, D.C., by J. O. Logan, Asst. Gen. Mgr. of Sales, Mathieson Chemical Corp., New York.

ALTHOUGH chlorine was discovered in 1774, it was not produced in the United States until about 1895. The compressed and liquefied chlorine familiar to all was not manufactured in this country until 1909. Consequently, the chlorine industry is comparatively an infant in years if not in size. Its growth parallels closely that of the automobile industry, and it is not boastful to say that chlorine is fully as vital to modern civilization as is the motor car. Chlorine is certainly the most important tool of the sanitation expert.

Growth of Chlorine Industry

In 1909, when liquid chlorine was first produced in this country, the production, as gas and liquid, totaled 25,000 tons (Table 1). Production climbed steadily, but not spectacularly, until the period immediately following World War I, during which the entire American chemical industry expanded significantly. The decade 1920–30 saw a 68 per cent increase in chlorine productive capacity, and there was an additional 75 per cent rise in the decade 1930–1940. Since 1940, under the impetus of impending and actual war conditions, the productive capacity has increased approximately 135 per cent.

At many times prior to 1940 the installed capacity was not completely utilized. This condition resulted in a decline in the price of chlorine, as shown in Table 2, and the competitive conditions stimulated much expensive research to find markets for the chemical.

Chlorine Products

The fact that chlorine is cheap and reactive has resulted in its use for the manufacture of many other chemicals. It facilitates the synthesis of many organic chemicals and today appears in the form of a multitude of chlorinated products, such as carbon tetrachloride, DDT insecticide, 2,4-D weed killer, freon and methyl chloride refrigerants, sodium hypochlorite household and laundry bleach solutions, vinyl chloride, polydichlorostyrene and other plastics, HTH, other sterilizing agents, and the specialized oxidizing and bleaching agent, sodium chlorite. In addition, chlorine is utilized in large quantities for the production of bromine, ethylene glycol antifreeze and synthetic glycerine. Many qualified persons believe that the growth of chlorine consumption in chemical manufacturing is likely to continue unabated.

Since the producers of chlorine manufacture many of the new products or operate the processes consuming chlorine, the tremendous increase in chlo-

rine production has not resulted in a proportionate increase in salable (merchant) chlorine. This is obvious from a study of Table 1. Between 1914 and 1947 the production increased 23 times. In the same period the amount for sale increased 15 times and the amount used in manufacturing increased 46 times. To cite an example of the growth of chlorine consumption by the manufacturer, one chemical company produces and uses in its own plants approximately 1,000 tons of chlorine per day. This quantity is over seven times the total used for water and sewage treatment.

At present all chlorine productive capacity is being used to the maximum, including the four government arsenal plants, which produce a combined total of about 300 tons per day. Additional capacity is being built, so that the end of 1948 will find the current productive capacity increased by approximately 900 tons.

Practically all new chlorine production is committed before operations commence. It now costs $75,000 to $80,000 to install a chlorine capacity of one ton per day, and expenditures of this magnitude are seldom made unless the consumption of the product is assured before the construction of the plant begins.

Position of Sanitation Users

Some pertinent statistics will show where the user of chlorine for sanitary purposes fits into this picture. As of 1929 the water and sewage trades consumed 31,000 tons of chlorine, or 11.4 per cent of the total production. In 1935 the quantity was 35,000 tons, or 9.75 per cent of the total. One of the last WPB allocation lists, covering 1944–45, indicated that the sanitary trades were consuming approximately 42,000 tons per year, which was only 3 per cent of the nonmilitary uses. At present probably about 50,000 tons is used for water and sewage treatment. This represents roughly 3½ per cent of the current total production, or 10 per cent of the chlorine shipped

TABLE 1

Estimated U.S. Production of Chlorine

Year	Daily Productive Capacity *tons*	Annual Production *tons*	Approximate Production for Sale *per cent*	Estimated Quantity for Sale *tons*
1909	175	24,754		
1914	400	60,424	75	45,400
1923	700	153,300	72	110,000
1927		202,700		
1930	1,050	241,800	70	169,000
1935	1,500	363,200	65	235,000
1937		506,900	65	329,000
1939	1,700	579,800	65	376,000
1941	1,900	696,472	50	348,000
1943		1,266,261	43	547,000
1945	3,250	1,192,081		
1947	4,300	1,400,000*	50†	700,000

* Estimated.
† Less than 35 per cent of total production is actually shipped from point of manufacture.

for sale. It is very evident that the water and sewage treatment demand for chlorine is not sufficient to influence materially the decisions regarding the quantity and location of additional chlorine capacity.

Competition for Chlorine Supply

Under present conditions there is much competition between consumers for the available chlorine. Many current demands are unsatisfied, a condition which seems likely to continue for some time. The chlorine producers and the users of chlorine for sanitation purposes must therefore recognize the problems associated with their relationship to each other. If an earnest attempt is made to eliminate these problems, the future demands for chlorine by sanitation users are more likely to be met.

TABLE 2

Price of Chlorine

Year	Price per 100 lb. Single-Unit Cars*	Cylinders†
1921	$6.00	$12.00*
1925	4.00	$7.00– 8.25*
1929	2.75	7.50– 8.50*
1932	1.65	6.00*
1935	2.00	7.50–13.00‡
1937	2.15	7.00–13.00‡
1939	1.75	7.50–13.00‡
1941	1.75	7.00–13.00‡
1943	1.75	7.00–13.00‡
1945	1.75	7.00–13.00‡
1947	2.00–2.25	8.75–15.00‡

* Price at works.
† Less than carload lot.
‡ Price f.o.b. destination.

By nature, sanitation demands are seasonal. Table 3 shows the month-by-month chlorine shipments to a group of sanitation users as a percentage of their total 1946 shipments. Both water and sewage treatment users are included in the data. The seasonal distribution of cylinder demand is similar. Since chlorine plants operate on a uniform rate of production 365 days of the year, the seasonal variation in chlorine demand by sanitation users presents a real problem to the producer. It sometimes causes hardships for industrial users who cannot get their chlorine as needed because of the preferential treatment accorded the sanitation users. By comparison, few chemical or industrial users of chlorine are subject to significant seasonal variations.

TABLE 3

*Monthly Chlorine Demand for Sanitation Use**

Month	Proportion of Total Yearly Shipments *per cent*
January	4.75
February	4.75
March	4.75
April	7.95
May	6.35
June	11.10
July	15.90
August	12.70
September	9.55
October	11.10
November	4.75
December	6.35
Total	100.00

* For group of users taking at least four tank carloads annually.

The chlorine demand for sanitation purposes is stable in the sense that the total usage remains steady year after year. The relation between the supplier and individual consumers, however, is frequently unstable. Changes of municipal administrations and their political implications often mean that the chlorine supplier is uncertain of the dependability of the customer. In several states, legislation authorizes

municipal officials to award supply contracts to agents in the community or within the state at a cost higher than that quoted by an out-of-town or out-of-state producer or agent. Only rarely does the local agent contribute to a sound business relationship. Many local and state regulations governing bids on chemicals are more appropriate for equipment or construction than they are for the purchase of material vital to the welfare of every person in the community.

Many sanitation users of chlorine are small. This means that the paper work and personal attention required is greater and more expensive per unit of chlorine than it is for larger consumers. Cylinder equipment is used less effectively when shipped to the small consumer. To date there has been no adequate formula developed to provide revenue to the chlorine producer commensurate with the expense involved in handling the orders of small consumers.

Equipment, whether cylinders, ton containers, or multi- or single-unit tank cars, plays an important part in the distribution of chlorine. Until recently new equipment was not obtainable, and though it is becoming available, prices are high. Because a cylinder is worth at least twice the value of its contents, it is imperative that the equipment be used under conditions which give the maximum number of trips per year. Users who order in excess of their needs or who retain equipment for long periods of time are jeopardizing their future supply of chlorine. The smaller user must, therefore, make a great effort to keep the equipment moving effectively.

Chlorine in cylinders is now sold on a delivered-price basis, and in tank cars chlorine is priced at the works with freight equalized. The constantly rising freight rates, warehousing and handling costs make it economically unsound to ship to certain destinations from certain producing points. To produce a ton of chlorine electrolytically requires 1.7 tons of salt and about 3,500 kwhr. of electric power. Cheap salt and power determine the location of chlorine plants, whereas population density is an important factor in the geographical distribution of chlorine demand. Merchant chlorine production is now centered in four areas: Niagara Falls, Detroit, eastern Ohio-West Virginia and the southwestern Gulf Coast. Most of the industrial consumption of chlorine is within or adjacent to these areas of production. By contrast, large sanitation markets for chlorine lie outside the regions specified. The manner in which such consumers can be served is increasingly a problem.

Safe Handling Measures

No paper on chlorine would be complete without mentioning the safe handling of this chemical. The chlorine producer and the consumer have a joint responsibility to see that human lives are not endangered by unsafe practices. Every user should make certain that chlorine is supplied to him in equipment properly prepared by a producer of integrity and financial responsibility. It must be certain that the operators and supervisors understand the nature of chlorine and the way to control potentially hazardous conditions which might develop accidentally. If the consumer has any questions regarding safety practices, his supplier should be requested to provide the desired information.

Summary

The chlorine industry has grown tremendously. The sanitation uses of chlorine, though increasing in total volume, have declined in relation to other markets. Most of the new chlorine production is being installed to meet the specific requirements of industries favorably located with respect to the producing point. There is not likely to be any surplus of chlorine in the near future. Sanitation users of chlorine anticipating a greater need for the chemical to be used for free residual chlorination, waste disposal treatment or increased pumpage should thoroughly investigate the availability of additional chlorine in their areas. All users of chlorine for sanitary purposes should examine their chlorine procurement procedures and eliminate those practices which may be troublesome to satisfactory supplier-consumer relations.

Dealing With the Public in Obtaining Rate Increases

By Leonard N. Thompson, Rennie I. Dodd and William R. Wise

A panel discussion presented on May 5, 1948, at the Annual Conference, Atlantic City, N.J.

Leonard N. Thompson

Gen. Mgr., Water Dept., St. Paul, Minn.

IT has been said that St. Paul, Minn., was one of the first cities to raise water rates in an attempt to keep somewhat in step with the spiraling costs experienced in the past several years. Whether this statement is correct or not, one increase was made in 1942, and a second went into effect on February 1, 1947, designed to provide about $208,000 more in operating revenues annually. The revised rate represented an increase of 10 per cent for the average customer and approximately 45 per cent for the largest water users. No bond issues of the department have ever been voted down by the citizens and the present rate increase as well as all previous ones has aroused little, if any, adverse public comment.

Water rates in St. Paul are set by the Water Board and approved in the form of an ordinance by the City Council. A very wise charter provision states: "Water rates shall be adequate for the maintenance of the Department, the payment of all interest and repair charges and the amortization of all indebtedness when due, and any officer violating this provision shall be guilty of a misdemeanor." But rate increases have met with general approval for other reasons as well, which will be discussed in this paper. Much of the department's success can be credited to a sympathetic press, an understanding and confident public and competent water boards.

The methods used in St. Paul have been so simple in technique, however, that it is possible to express only in general terms the few basic rules to be followed in seeking public support. Perhaps it is the very simplicity of these rules which has sometimes caused them to be overlooked.

Appraisal of Rates

This panel is not intended to discuss rates as such, but rather the means of obtaining public acceptance with a minimum of adverse reaction. Nevertheless, a few introductory words on the subject of rates appear to be in order. Current price levels make it the duty of every manager to study and consider carefully the adequacy of his present rates. Never before has the water superintendent been more justified in making a careful analysis of his rate of return in comparison with the increased costs of maintenance and operation. *Without crying wolf, the author wishes to suggest the possibility that those who have been coasting year after year on the same rates have either enjoyed rates which were too high (based on prewar price levels) and are now living off accumulated*

cash surpluses, or else are permitting their plants to slip backward and will most certainly, sooner or later, be faced with the problem of raising rates. If this becomes necessary when other costs are at a low ebb or at least on the decline, the resultant public reaction will, of course, be unsatisfactory. Although high prices have indicated the need for rate increases, other factors in the past few years have had a tendency to dull the perception of water works officials and have lulled them into a false sense of security. One such cause has been the enforced delay of much needed maintenance.

If water rates need revising, now is the time to do it. There have been a number of excellent papers published in the JOURNAL on the establishment of proper and equitable rate structures. The recent articles by Louis R. Howson (1, 2) should be carefully studied by all superintendents. His reference to the fact that the capital investment of 100 works studied had increased 67 per cent from 1925 to 1945 while the number of consumers increased only 27 per cent clearly indicates that investment costs have far exceeded revenue.

Promotion of Rate Increase

A successful rate campaign must consist of two very essential elements: first, a justifiable rate structure; and second, an effective and positive promotional background—that is, a continuous policy of maintaining good public relations.

The first step—and a very important one—in proposing a rate change is the proper presentation of facts to the proper people: gaining the interest and support of the chamber of commerce, the service clubs and any other organizations which claim an interest in good government. This, of course, includes the newspapers—specifically, those members of the press who determine its public policy. The sympathy, interest and cooperation of the news reporter is most desirable and essential and should indeed be cultivated, but the nature of any news items written by the staff reporters will not for long be at variance with the editorial policy of the paper. Editorial policy does not always mold public opinion, but a public at first not actually opposed to a rate change most probably will easily and quickly follow the lead of a local paper conducting a negative campaign. An editorial opinion once formed and publicly expressed is seldom reversed, so it is important that facts—and correct facts—be presented logically and made available at the right time—certainly before the utility finds itself on the defensive. It is therefore necessary to keep proper statistical records over the years. These include, for example, records of all the costs of production and operation, fixed charges, labor costs per million gallons, and average rates of return per million gallons at each step. Such data are vitally necessary in any argument for a rate increase.

In dealing with the public it is always essential to keep in mind that a water business is a big business and an important business, but, at the same time, there should be no attempt to make it a mysterious business. Informing the public is the first step in gaining its interest. People cannot appreciate what they do not understand. Logically, therefore, on the day a new rate takes effect the management should begin to prepare the way for a future schedule or additional improvements whenever they may be needed. Success with the public de-

pends entirely upon the background built up over the years. Of course, it is not meant to imply that rate changes should follow each other in close sequence or without proper justification. The rate should rather be one which can be stabilized over as long a period as possible, since too much tampering will destroy public confidence.

Although water utilities are continually raising the standards of water quality and educating the consumer to them, the utilities fail to carry on any educational or promotional campaign to demonstrate that increased costs must generally accompany better quality.

The author is a firm believer in the theory that enough advertising will sell anything. However, as most water utilities have what amounts to a monopoly in their community, they do not require a competitive sales campaign, but one to make the people appreciate their product. It is of primary importance to convince the public that water is not only valuable but also hard to get and difficult to treat. Constant repetition of this idea is a promotional approach that will bear fruit.

Water utilities, instead of supporting the belief that water ought to be as cheap as air, should rather sell the idea that water rates are reasonable and are as low as good business administration justifies. Water works men must impress upon themselves, as well as on others, that water today is a commodity often not even abundant, requiring the skill of a technician to perfect and the ingenuity of an engineer to deliver. The water delivered by the utility is a finished, processed product, and when speaking of rates it is not necessary to be apologetic. Nor should management be dominated by the thought that water rates in one city cannot be higher than those in a neighboring city even though the basic conditions are radically different. With a good background—honest statements of facts and the courage of conviction—public confidence and acceptance of proposed rate increases or other improvements is not too difficult an objective to achieve.

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Rennie I. Dodd

Exec. Mgr., Chester Municipal Authority, Chester, Pa.

On November 1, 1946, in order to finance a new source of water supply, the Chester Municipal Authority increased its rates. This was done with excellent customer reaction and with a minimum of objections. It is, of course, always of great importance to keep the public in the right frame of mind. To do so in the face of a substantial price increase is, it is felt, of even greater significance and points to an outstanding public relations job, well worth the time, effort and expense involved.

Chester Supply

Chester is located on the Delaware River, midway between Philadelphia and Wilmington. The Delaware River is the present source of supply for the entire service area of the authority, comprising, in addition to the city of Chester, five near-by boroughs and five townships—a district approximately seven miles long and four miles wide, serving an estimated population of over 100,000.

The Delaware River is entirely unsatisfactory as a source of supply. It is highly polluted with sewage and industrial wastes in spite of the fact that every effort has been made to overcome the condition. Although research indicates that the taste and odor problem can be controlled, the river, being a tidal estuary, is subject to salinity during periods of drought. Since 1930 a serious salt water condition has occurred almost yearly.

Because of this increasing salinity, with its resultant hardship on industry and its objectionable characteristics for the domestic consumer, it became more and more apparent that the Delaware River would have to be abandoned as a source of supply.

In 1929, the Public Utility Commission held a hearing on the quality of Chester water and ordered the water company to make a study of possible new sources of supply and report its findings to the city. The study was made and the substance of the report indicated that, if the city permitted a rate increase, a new and satisfactory supply could be secured; otherwise, only limited additions and repairs to the existing plant would be possible, which would improve but not entirely correct the condition. The city did not agree to a rate increase at that time.

In 1939 the city of Chester created an authority which purchased the water company. One of the principal objects of this acquisition was ultimately to secure a new source of supply. To this end, investigations were started almost immediately. During the war, however, little progress was made.

Public Relations

In 1946 the Chester Municipal Authority decided it was timely to employ the services of a consulting engineer and to take the first step toward securing the kind of public relations necessary to achieve its objectives. A meeting of representative citizens and members of the press was held, at which definite plans to procure a new source of supply were made known, as well as the authority's intention of obtaining the services of an outstanding engineer. Those present at the meeting were informed that the task was so great that, without their full cooperation and support, it would be useless even to try to get the badly needed water supply. The citizens were urged to back the authority in every way and were told that it was relying on them to do so. The qualifications of outstanding water works engineers, secured prior to the meeting, were presented to the group and its aid was enlisted in making the final selection.

After exhaustive studies, including some topographical surveys of sites for dams and impounding reservoirs, the engineers made their recommendations, which involved the purchase of land. In order to avoid the possibility of a land grab, it was extremely important that the negotiations should not be made public. At this time it was decided to take the second step in the public relations program. Certain members of the press were given the full story and were told the authority had absolute confidence that they would not divulge the information until its release was approved. This belief in the press was well founded: the story was kept in complete secrecy.

In the beginning the local papers were definitely unfriendly. Their first reaction was to oppose and belittle everything the authority was trying to do. Thus, it was necessary not only to sell the public but also to convert

the press. The authority finally accomplished its purpose by convincing the newspapers of its sincerity and of the importance of the project to the community.

Over a period of months strategic land was purchased and agreements signed. It was then time for step number three in the public relations plan. Once again those who had attended the first meeting—both representative citizens and members of the press—were brought together. All the details of the project were disclosed for publication. The local press devoted almost an entire issue to the project, dozens of pictures and illustrations were included and the story was given the entire front page. That meeting marked the end of hostilities on the part of the press and the beginning of an outstanding public relations job.

Many more steps along the road to success in dealing with the public have been taken since that time. Experience has shown that chief among these is keeping the public informed. To do this the authority employs many media —meetings, motion pictures, press releases and others. The authority saw to it that its own employees became special emissaries of good will by educating them in all phases of the new project. As a result of discussion groups, they were able to answer all questions intelligently and were capable of dispersing rumors.

Because the source of supply selected was in a new territory approximately 40 miles from Chester and required the construction of an impounding dam, a water purification and pumping plant, various storage reservoirs and a 40-mile transmission pipeline, the authority was once more faced with a public relations job. Backed by previous experience, meetings were immediately arranged with community and civic groups; the entire plan for the new project was presented and discussed. Little by little, good will was established. When inquiries began to arrive from prospective consumers, the authority felt the foundation had been laid for satisfactory public relations in the new area.

Early in the publicity program, after the sympathy of the press had been won and the loyalty of the public seemed assured, it was announced that in order to finance the new supply it would be necessary to increase rates. An adequate rate schedule was computed and went into effect with little objection, none of it organized. Bonds have been issued and excellent progress has been made on the new project. Contracts were awarded for building the dam and water purification plant at Pine Grove, Chester County, Pa., on March 25, 1948.

Conclusion

In dealing with the public to obtain price increases, or in any other phase of business affecting the people, their good will, cooperation and loyalty can best be secured by keeping them posted on all of the facts, all of the time, and by taking advantage of every opportunity to sell the integrity of the organization and its sincerity of purpose.

William R. Wise

Mgr.–Engr., Commissioners of Public Works, Newberry, S.C.

In order to understand the public relations problems involved in securing popular support for rate increases in Newberry, S.C., some acquaintance with the community background is required. Newberry is a typical small

southern town of approximately 8,000 persons, located in the central portion of South Carolina. Its main industry consists of three textile mills. The public utilities—water, electricity and sewerage—are municipally owned and are operated under an elective board of three commissioners. Like all communities which had no influx of industries in the war years, Newberry was dormant during that period. With no demand for water plant expansion, no capital improvements were made.

At the close of World War II, the South—Newberry included—began to visualize an industrial expansion program. The Newberry Chamber of Commerce became active and approached a number of industries about locating new plants in the city. Very shortly afterward, the water department was requested to provide information on its ability to furnish water for various industrial purposes. An analysis of water plant facilities was immediately undertaken, and it was found that not only were they inadequate for industrial needs but they would also be insufficient to meet domestic requirements by 1949, because of new residential construction and the increased demand in existing homes due to the higher standard of living.

With the aid and support of the local Chamber of Commerce, a citizens' meeting was called early in 1946 to discuss the problems and select a method of financing plant expansions. In 1942 the South Carolina State Legislature had passed the Revenue Bond Act which enabled municipalities to finance utility improvements by the use of revenue bonds. Up to that time the only methods used to finance improvements were to draw from a general surplus or issue general obligation bonds. Because the public had not been schooled in the details of the Revenue Bond Act, this was the initial job to accomplish. At the first citizens' meeting there was a great deal of enthusiasm, but the number of persons present was less than 50. This lack of attendance made the department realize that it had sorely failed in creating public interest in its activities. The failure might well be attributed to the fact that the public was unfamiliar with the over-all operation of the department.

The first citizens' meeting was given good publicity in the local papers and did help create a little more interest. At the second meeting the attendance was better, but still only a small percentage of the population was represented. The water department presented an itemized list of utility improvements needed and their estimated cost. It also recommended that these improvements be accomplished through the use of revenue bonds and that both water and electricity rates be increased to provide sufficient funds to retire the bonds. The small group of citizens present at the meeting concurred in these proposals.

Rate Referendum

The city officials decided that the department did not have sufficient support for the proposed water and electric rate increases and requested it to hold a referendum in order to poll all the customers. This referendum was to be conducted by mail, permitting each consumer who received a water and light bill to express his opinion on a water rate increase of approximately 50 per cent and an electric rate increase of approximately 25 per cent to finance improvements.

The request for a referendum caused the department great anxiety, for if it

failed, the city administration could hardly support the increase in the face of the voters' opposition. The department thereupon started searching for public relations data in an effort to find out how to gain public support.

It was decided to use the local newspapers for publicity and to forward a mimeographed letter to each customer explaining in detail the improvements that were needed and why a rate increase was necessary to finance them. Along with this letter a self-addressed envelope and card were enclosed for the customer to indicate whether or not he was in favor of raising the water rates. The letters and cards were mailed by August 15, 1946, and a return was requested by August 30, 1946.

Prior to the mailing date several talks and discussions were conducted before various civic organizations. These groups provided material assistance, as most of them actually inserted in the local papers a notice of their support of the program. Full cooperation of the press was also obtained, and the problem and referendum received good publicity.

A total of 1,505 letters and cards were mailed to customers and 818 were returned. Of these, 509 expressed themselves in favor of increasing rates and 309 were opposed. The water rates were increased approximately 55 per cent, and in the first month of operation under the new rate structure there were only three real complaints.

In the author's opinion, the principal public relations lesson to be learned from the Newberry method of obtaining a rate increase is to take the public into confidence by keeping them informed of all the operations of the water department. After all, the consumers are the stockholders of any municipally owned water utility. A well-informed public proved a valuable asset in Newberry, and this will probably hold true for any community.

Determination of Economical Pipe Diameters in Distribution Systems

By Vance C. Lischer

A contribution to the Journal by Vance C. Lischer, Horner & Shifrin, Cons. Engrs., St. Louis.

THE numerous factors which control the design of a water distribution system are so complex and often so incapable of rationalization that, up to the present, the problem of determining the most economical combination of pipe sizes, pumping head and elevated storage in a water system has been badly neglected. A general solution is impractical in systems of rugged terrain because the problem there is exceedingly complex. In a simple system, however, where the terrain is level, it is possible to produce general equations showing the interdependence of the variables. It is the purpose of this paper to develop the equations for a simple system with the expectation that the knowledge of the interdependence of the variables in these cases might produce a better understanding of the problem and, perhaps, lead to better designs.

The outstanding advances in distribution system analyses of the last few years by Cross (1), Doland (2), Aldrich (3) and Camp and Hazen (4), improving upon the earlier work by Freeman (5), have contributed much toward making solutions of certain phases of the problem possible. These methods of analysis, however, are only the means to study a system once it is designed; or possibly to examine laboriously a few of the infinite combinations of pipe sizes, input heads and elevated storage—only one combination of which provides the lowest annual cost.

Howson (6) has emphasized the importance of the distribution system and the additional attention it deserves. Probably the most valuable contribution toward the design of distribution systems is that of Camp (7), in which a definite technique is developed for the determination of economical pipe sizes.

In this paper, the principles of design developed by Camp are applied to a simple problem and the effects of the variables on the economical pipe size are shown. It is the author's conviction that the results of this simple exploration will be helpful in providing a proper understanding of the factors affecting a more complex design, particularly because the process of solution of the simple problem shows the interrelation of the variables.

The Problem

The problem, simply stated, is to find the most economical combination of pumping capacity, transmission main sizes, elevated storage and pumping head to serve a community at the lowest annual cost. Otherwise stated, the problem is one of finding that combination of fixed charges on invested capital in pumps, mains and storage, plus

power cost to overcome pipe friction, plus other operating costs which give the lowest annual cost. Before proceeding with the method of solution, the various factors involved will be listed and discussed. These include: (1) the initial cost of pipelines; (2) the initial cost of pumping stations; (3) the initial cost of storage; (4) the cost of invested capital; (5) depreciation; (6) the maintenance of physical properties; (7) the minimum pressure to be maintained in the street at consumers' taps; (8) the cost of power; (9) pumping efficiency; (10) the variation in demand for water; (11) the pipeline carrying capacity; and (12) future demands.

Pipeline Cost

In any given locality, it is possible to determine the cost of various sizes of mains in place. A decision must be made initially regarding the kind of pipe considered best for the local conditions. Above a certain size, it may sometimes be desirable to consider a different type of pipe, which means that separate formulas must be obtained and some trial and error determination will probably be necessary in the study.

Although it is understood that unit costs will vary within a community, depending upon the particular routing chosen, these factors should tend to average out in a specific problem and should not affect the end result appreciably. Camp (7) gives an equation for pipe costs as a function of diameter, using basic unit costs. Figure 1 shows cast-iron bell-and-spigot pipe costs from several different sources, plotted against diameter on logarithmic paper. (A 5 per cent allowance is made for valves and fittings in the curve chosen for this

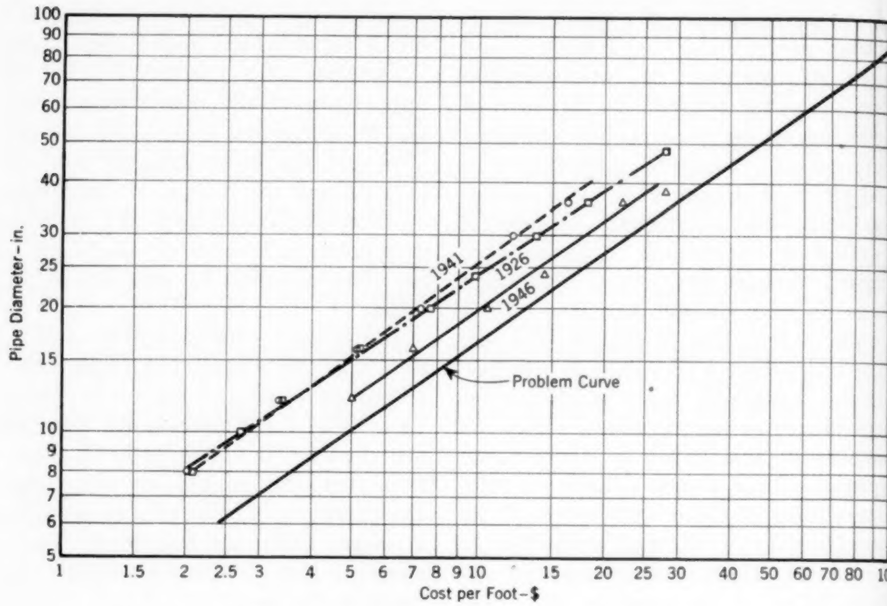

FIG. 1. Pipe Diameter and Cost of Mains

analysis.) The costs follow straight lines remarkably well. From the straight-line plotting, exponential equations can be determined relating diameter to cost. The equation given below, for the extreme right curve in the graph, is used in the analyses made in this paper and is considered to be fairly representative of 1947 costs:

$$\text{Pipe Cost per 1,000 ft.} = 197D^{1.40} \quad \ldots (1)$$

D is the diameter in inches, and the cost is expressed in dollars.

Pumping Station Cost

In the determination of the cost of overcoming friction head, the fixed charges on a portion of the investment in pumping station facilities should properly be considered. The basic problem is concerned with evaluating the total pumping station head—that is, the static head plus the system friction head—to be utilized in lieu of larger transmission mains. Obviously, pump, motor and hence the over-all cost of the station are affected if the total head is increased.

Early in the analysis of such a problem, it is necessary to determine the motive power to be used for pumping. Once this is settled, the general arrangements of the pumping station and the type of pumps and driving units must be decided upon. Thereafter, the incremental cost should be found for the incremental pumping head.

In this phase of the problem, rather broad assumptions are made in this paper about the ratio of the incremental cost to the base cost. In a particular problem, these elements of cost can be segregated and a realistic analysis made.

As the basis for the demonstration of the problem under consideration, electrically operated pumps using purchased power are assumed and the cost of providing such facilities is taken roughly from the approximate average unit cost of four electrically driven high-service pumping stations constructed before World War II.

The unit for consideration is the cost of pumping facilities for 1 mgd. of installed capacity lifted one foot. Using such a unit seems to be justified, since the total power required is directly proportional to capacity and head. To determine the unit cost, the total cost of such a station is divided by the total installed pump capacity (in million gallons per day) times the pumping head. The unit costs thus calculated are \$12, \$15, \$19 and \$25 for the four stations. A figure of \$30 is considered suitable for use in this problem in the light of present prices.

In producing an equation consistent with the variables employed in the problem, instead of using *total installed* capacity, it is necessary to use *average daily* capacity. To determine the relation between these values, the percentage of reserve capacity to be available at the peak must be established. In this problem, the amount is assumed to be 25 per cent of the total installed capacity (this is independent of emergency elevated storage or of the effect of reserve power supply facilities). Also, in this problem, the duration curve of pumping rates (Fig. 2) gives the maximum hourly pumping rate as 2.32 times the average rate. Combining these two factors (the reserve capacity required and the relation of the maximum rate to the average), the installed capacity becomes 310 per cent of the average. Applying this percentage to the average adjusted cost per million gallons a day raised one

foot ($30 for the four pumping stations mentioned in the preceding paragraph), a proper equation for the initial cost of the pumping stations, in dollars, is:

$$\text{Pumping Station Cost} = 93QH \quad (2)$$

in which H is the total pumping head in feet and Q is the average pumpage in million gallons per day.

Equation 2 may also be expressed thus:

$$\text{Pumping Station Cost} = 93QH_1 + 93QH_2 \quad (3)$$

in which H_1 is the static head and H_2 is the maximum friction head.

Equation 4 gives the relationship of the maximum friction head to h (the friction head at average Q per 1,000 ft. of pipe) in a system where there is no elevated storage for equalizing purposes:

$$H_2 = 2.32^{1.85}hL = 4.73hL \quad (4)$$

L is the length of the system in 1,000-ft. units. Combining Eq. 3 and 4:

$$\text{Pumping Station Cost} = 93QH_1 + 440QhL \quad (5)$$

In this study, only the pumping station cost related to the friction head need be considered. It is reasonable to assume that costs due to increments of head above the static head should not be calculated at the same unit cost as the basic requirements. It is assumed that the constant for the equation for the cost of pumping to overcome pipe friction will be 50 per cent of the value given in Eq. 4. The equation to be carried forward in this analysis, therefore, is:

$$\text{Cost} = 220Qh \quad (5a)$$

in which the initial pumping station cost of overcoming pipe friction is expressed in dollars per 1,000 ft. of system.

Elevated Storage Cost

Elevated storage may normally be required in a water system for one or more of these reasons: (1) to provide reserves against the failure of pumping facilities; (2) to provide fire reserves; (3) to equalize pumping rates in order to reduce plant capacity, improve pump efficiency, reduce demand charges or power plant requirements, reduce installed pumping requirements or reduce transmission main requirements.

The required storage for reserve supply must be calculated from a consideration of the vulnerability of the source of supply. In most systems, reserves are needed unless conditions peculiar to the supply guarantee the continuity of service. Such factors may be a multiplicity of sources, unusual plant stand-by or gravity supply from an impounded reservoir. Storage for this purpose, as well as for fire reserves, should not be encroached upon for equalizing purposes.

If the source of supply involves elaborate purification facilities or costly wells, it will probably be economical to install ground storage at the plant sufficient to equalize the rate of flow on the maximum day. Since the equivalent storage to serve the same purpose could be provided as elevated storage in the distribution system, the difference in cost to elevate this storage is all that can justifiably be considered in analyzing the size of mains to be installed or the amount of pumping facilities to be provided.

In this problem, the incremental cost of elevated steel storage tanks over steel ground storage tanks is taken as 10¢ per gallon. If ground storage

reservoirs are to be of concrete, it would still be proper in the economic analysis to use the differential cost for steel tanks, since the elevated steel tanks would not be comparable to concrete ground storage on the basis of the life of the investment.

Cost of Invested Capital

There is no general agreement on the method of determining the interest rate to be used in an economic analysis. Therefore, for the purpose of showing the effect of this factor, interest rates in 1 per cent increments from 1 through 5 per cent are used.

Depreciation

As with interest rates, there is wide difference of opinion about the method of depreciation to be used. In order to take into consideration the earning capacity of the depreciation reserve, and also to provide a uniform annual depreciation allowance, the sinking fund method of depreciation is employed in this analysis with the interest rate being equal to the rate used for invested capital.

The life span adopted for depreciation purposes is 100 years for mains, on the assumption that they will be of cast iron, and 30 years for pumping equipment. The annual depreciation allowances—based on different interest rates—resulting from the sinking fund method are shown in Table 1.

Maintenance

Maintenance is regarded in this paper as a function of the initial cost of the installation. Annual pipe maintenance is considered to be 0.25 per cent of the initial cost and pumping station maintenance 2 per cent of the initial cost.

Minimum Pressure

Since consideration is given in this problem only to primary feeders, the minimum pressure to be maintained is taken as 50 psi., thus providing a margin of at least 20 psi. for loss of head in secondary feeders in residential areas. Where the critical pressure area is commercial or industrial, somewhat higher basic pressures may be required for fire protection.

Power Cost

The power cost element in the problem can be exceedingly complex, particularly if power is purchased under a contract involving a demand charge with a varying energy rate. The problem is also made more complex if the unit cost of power, whether for a steam or diesel plant, varies with the amount of load on the plant. Since the energy given the water to overcome friction is only part of the total energy delivered to the water, incremental unit costs of power may sometimes be used. On this basis, it may be justified to consider only fuel costs, since operating labor and supplies and expense will not be increased by the greater load. It would be necessary to take into consideration such added fixed charges as are required only for the increments of power plant investment needed for the greater loads.

TABLE 1

Interest and Depreciation Rates

Interest Rate *per cent*	Depreciation Rate 100-yr. Life	30-yr. Life
1	0.0059	0.0287
2	0.0032	0.0246
3	0.0016	0.0210
4	0.0008	0.0178
5	0.0004	0.0151

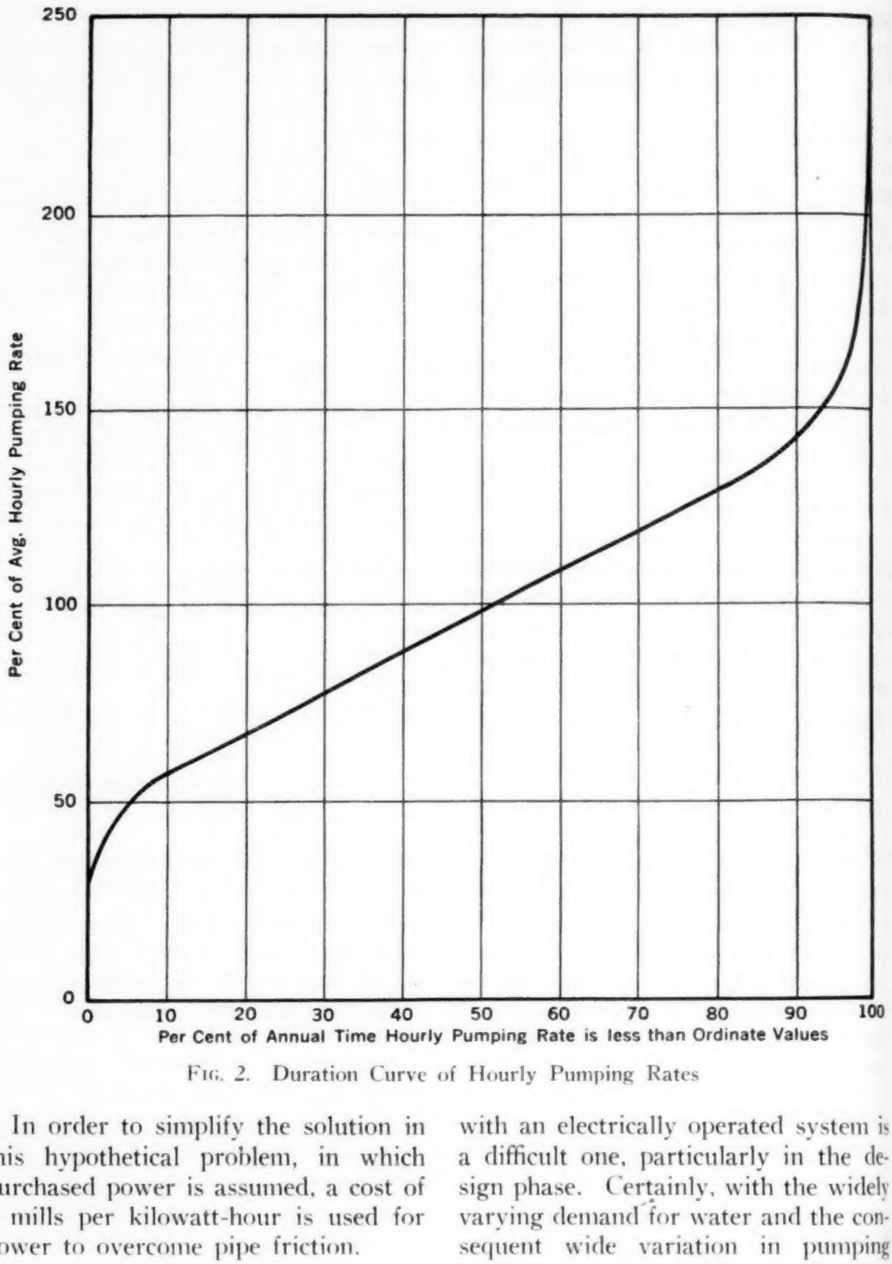

FIG. 2. Duration Curve of Hourly Pumping Rates

In order to simplify the solution in this hypothetical problem, in which purchased power is assumed, a cost of 7 mills per kilowatt-hour is used for power to overcome pipe friction.

Pumping Efficiencies

The problem of ascertaining the probable average efficiency attainable with an electrically operated system is a difficult one, particularly in the design phase. Certainly, with the widely varying demand for water and the consequent wide variation in pumping heads in a system where no distribution system storage is used for equalizing purposes, it may become difficult to realize a high average efficiency.

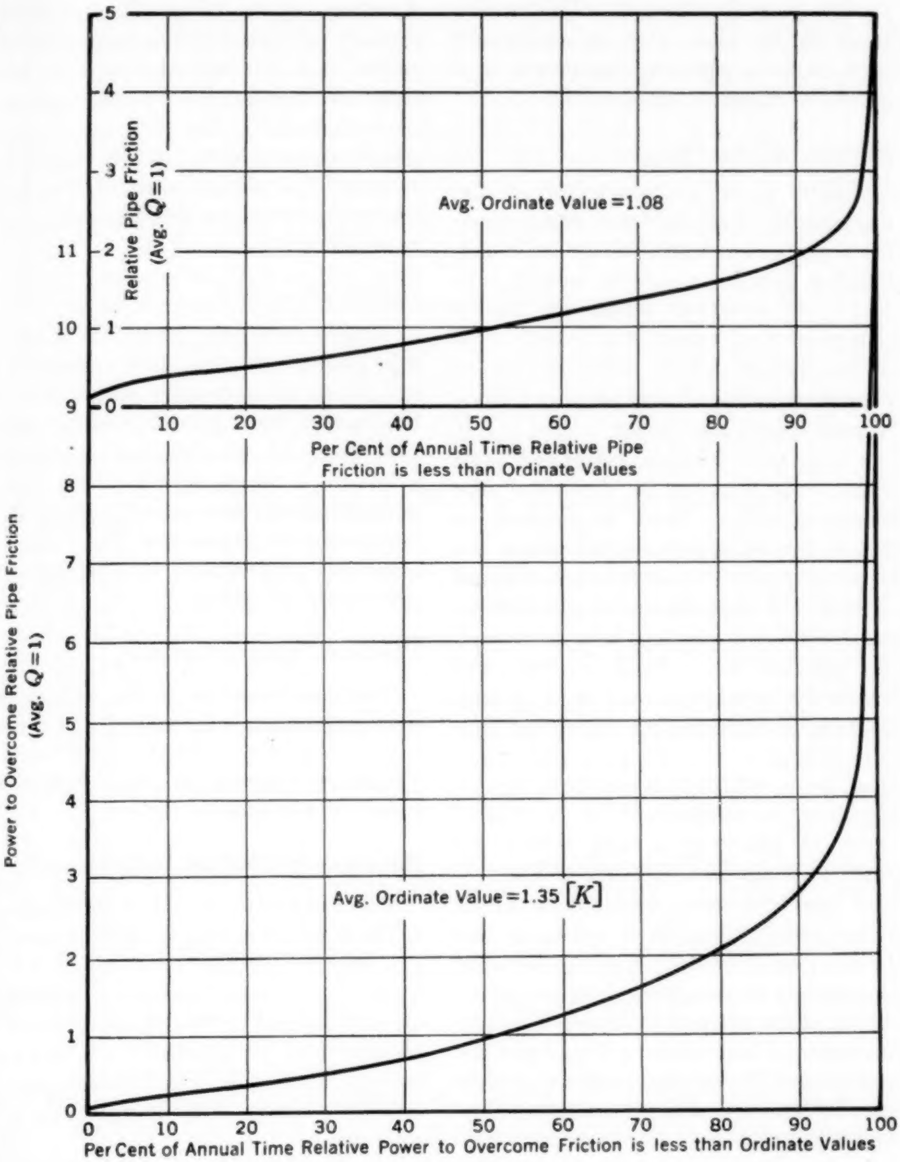

Fig. 3. Duration Curves of Friction Head and Power to Overcome Friction

In any particular problem, after pumping heads have been determined from a consideration of the most economical sizes of mains to be used, it will be necessary to recheck the figure originally assumed for wire-to-water efficiency. In this demonstration problem, an average wire-to-water efficiency of

75 per cent is adopted. This would seem to be reasonable of attainment with modern pumping equipment in a carefully designed station.

Varying Water Demand

Fairly accurate knowledge of the duration of pumping rates is necessary for a proper evaluation of the problem, but few data are available on this subject. A duration curve of hourly pumping rates, taken from a study (8) of the Toledo, Ohio, water system, is presented in Fig. 2 and used as a basis of analysis in this paper.

Using this duration curve as basic data, it is possible to determine the factor K which must be applied to Eq. 8 (given later) to determine the cost of power to overcome friction. The symbol Q in Eq. 7–9 (given later) represents the average daily pumpage. To calculate the average friction, and hence the average power to overcome friction, it is necessary to obtain factors related to the pumping rate-duration curve. Where a constant service pressure is maintained at a critical point in the system, and where the rates of usage at all points in the system bear the same relationship at all times, the friction head varies as the 1.85th power of the pumping rate and the energy to overcome friction as the 2.85th power, using the Hazen-Williams formula. The curves in Fig. 3 are the pumping rate-duration curve raised to the 1.85th and 2.85th powers. The factors applicable to these curves, which are also shown in the figure, are obtained by integrating the curves. The significance of the averages of the curves given in Fig. 3—1.08 for the upper curve and 1.35 [K] for the lower —can best be explained thus: Where the pumpage varies as shown by the duration curve (Fig. 2), the same amount of frictional loss would be obtained if a uniform rate of flow 1.08 times the average hourly rate were experienced; and the same amount of power to overcome friction would be required if a uniform rate of flow 1.35 times the average hourly rate were experienced.

Future Demand

Where the future growth of the system must be considered, it is necessary to assume some definite period of time over which the analysis is to be made. If a growth curve has been assumed, a modified duration curve of water demand can be determined. From this curve new K factors for Eq. 8 can be obtained graphically in the manner previously described.

Pipeline Carrying Capacity

The determination of the economical diameter involves the use of a flow formula. In this analysis, the Hazen-Williams formula is used and a C value of 130 is assumed.

Solution for Simple System

The system upon which the analysis is made is one which is *in level terrain* and which consists of a single trunk supply line with ten equal take-offs equally spaced. Should several trunk supply lines be assumed, the analysis will be applicable if a proportionately smaller average daily pumpage is also assumed.

The further assumption is made in this simple problem that the pattern or duration curves of usage for all take-offs are identical. In the first round of analysis, it is assumed that there is no elevated storage in the system.

The determination of the sizes of the mains for each of the components of the system are based on the method developed by Camp (*7*). In this method, an assumption is made about the power cost chargeable to any component transmission main in determining its economical size. The chargeable cost is for the quantity of power required to raise the flow in the main (plus all of the take-offs upstream) by the amount of the friction head in that main. This is a logical assumption because all the flow taken off upstream from a given main must be raised high enough to overcome the friction in that main.

The symbols used in the basic equations which determine the economical diameters in the system described are:

D —Pipe diameter (in.)
D_1—Diameter of first main from pumping station (in.)
R —Rate for annual fixed charges on pipe investments (interest plus depreciation)
M—Annual maintenance cost of pipe expressed as proportion of pipe investment
Q —Average pumpage (mgd.)
r —Rate for annual fixed charges on pumping station investment (interest plus depreciation)
m —Annual maintenance cost of pumping station facilities, expressed as proportion of pumping station investment
h —Friction head (ft.) per 1,000 ft. at Q
h_A—Average friction head (ft.) per 1,000 ft. at Q, for system with ten equally spaced equal take-offs
K —Factor depending on duration curve of pumping rates
P —Cost of power (\$/kwhr.)
E —Average wire-to-water efficiency
C —Hazen-Williams C
f —Proportion of total Q taken off downstream from any given reach of pipe
G —Cost of main (\$/1,000 ft.)
G_A—Average cost of mains (\$/1,000 ft.) in system of ten equally spaced equal take-offs
T —The expression

$$\left[\frac{220(r+m)+\dfrac{1{,}146\,KP}{E}}{R+M}\right]$$

The basic equations are given below. From Eq. 1, the annual cost of pipe (\$/1,000 ft.)

$$= (R+M)197D^{1.40} \quad \ldots\ldots(6)$$

From Eq. 5a, the annual cost (\$/1,000 ft. of system) of incremental pumping facilities to overcome pipe friction

$$= 220(r+m)Qh \quad \ldots\ldots(7)$$

The annual cost (\$/1,000 ft. of system) of power to overcome pipe friction

$$= \frac{1{,}146KPQh}{E} \quad \ldots\ldots(8)$$

From the Hazen-Williams formula:

$$h = \frac{104{,}000^{1.85}f^{1.85}Q^{1.85}}{C^{1.85}D^{4.87}} \quad \ldots(9)$$

The total annual cost is the sum of Eq. 6, 7 and 8. The economical diameter giving the minimum annual cost can be determined by differentiating and equating to zero. The results of this manipulation, after substituting Eq. 9 for h, are:

$$D = \left[\frac{220(r+m)+\dfrac{1{,}146KP}{E}}{R+M}\right]^{0.1595} \times \frac{15.86f^{0.295}Q^{0.455}}{C^{0.295}} \quad \ldots(10)$$

$$h = \frac{2{,}716 f^{0.413}}{\left[\dfrac{220(r+m) + \dfrac{1{,}146KP}{E}}{R+M}\right]^{0.777}} \times C^{-0.413} Q^{-0.366} \quad ..(11)$$

$$G = \left[\frac{220(r+m) + \dfrac{1{,}146KP}{E}}{R+M}\right]^{0.223} \times \frac{9{,}438 f^{0.413} Q^{0.637}}{C^{0.413}} \quad ..(12)$$

From the relationships shown for factor f in Table 2, Eq. 13 is derived for the average loss of head in the system. From this equation the total pumping heads can be determined. Equation 14 is similarly derived for the average cost of mains; and from Eq. 14 the total cost of the trunk main system can be determined. Equations 11 and 12 are multiplied by 0.7485, the average of $f^{0.413}$. The symbol T replaces the expression in brackets in Eq. 11 and 12:

TABLE 2

Diameter, Friction Head and Cost of Mains

Main From Pumping Sta.	f	Diameter $f^{0.295}$	Friction Head and Cost of Main $f^{0.413}$
1st	1.0	1.0	1.0
2nd	0.9	0.969	0.957
3rd	0.8	0.936	0.912
4th	0.7	0.900	0.863
5th	0.6	0.860	0.809
6th	0.5	0.815	0.751
7th	0.4	0.763	0.685
8th	0.3	0.701	0.608
9th	0.2	0.622	0.514
10th	0.1	0.507	0.386
			Average 0.7485

The relationships between the diameters, friction losses and costs of the component mains in a system with ten equally spaced equal take-offs, determinable from the above equations, are given in Table 2.

Table 2 shows what should be evident from the method for determining the economical diameters: that the loss of head per unit of length decreases in mains farthest from the pumping station. It indicates that a gradient contour map of a distribution system (in a level system) should show wider spacing of contours toward the extremes of the system.

$$h_A = \frac{2{,}033}{T^{0.777} C^{0.413} Q^{0.366}} \quad ....(13)$$

$$G_A = \frac{7{,}064 T^{0.223} Q^{0.637}}{C^{0.413}} \quad ....(14)$$

To determine the diameters of the component mains in the system, the diameter of the first main is ascertained by means of Eq. 15 and is multiplied by the factors given in Table 2. For the first main in the system, the factor f is 1.

$$D_1 = \frac{15.86 T^{0.1595} Q^{0.455}}{C^{0.295}} \quad ...(15)$$

Table 3 has been compiled for various interest rates, based on the following values for the elements making up the factor T: $K = 1.35$, $P = 0.007$, $E = 0.75$, $m = 0.02$ and $M = 0.0025$. (Depreciation is calculated by the sinking fund method, assuming a 30-year life for pumping equipment and a 100-year life for mains.)

Table 4 gives the values of h_A, D_1 and G_A for various interest rates, based on a C of 130. Using Table 4, Fig. 4 has been drawn, showing the values of h_A, D_1 and G_A for various values of $\dot{Q}$.

From a practical standpoint, the pipe sizes obtained from graphs and tables similar to Fig. 4 and Table 2 can be used only as guides to the selection of the commercially available sizes to be used in the system. The final choices, using commercial sizes, should be made on the basis of achieving the total cost and loss of head for the system shown for the theoretical sizes. For example, Table 5 shows commercial sizes, selected for a system with Q equal to 20 mgd., which give an over-all performance comparable to the theoretical sizes. A 3 per cent interest rate is assumed.

A number of interesting observations can be made from the results of this analysis, shown graphically in Fig. 4. In general, the background cost data for the graph are typical. These observations are discussed in detail below.

TABLE 3

Interest Rate and Values of T

Interest Rate *per cent*	T	$T^{0.777}$	$T^{0.1595}$	$T^{0.223}$
1	1,487.	291.7	3.206	5.098
2	1,115.	232.2	3.062	4.781
3	881.5	194.3	2.950	4.537
4	729.3	167.7	2.862	4.350
5	627.0	149.1	2.794	4.205

Importance of Interest Rate

Perhaps the most disturbing factor in the analysis is the large part played by the value placed upon money. It has always been apparent that it is an important element in any engineering problem. This analysis shows how important the assumed interest rate is in the determination of the economical pipe size.

Using Fig. 4, it can be seen that, for a transmission line of ten take-offs in a system 40,000 ft. long with an average pumping rate of 20 mgd., the investment would be $1,300,000, assuming a 1 per cent interest rate, and $1,070,000 for a 5 per cent rate. This is a sizable difference of $230,000, or about 21 per cent, in the first cost.

When the money for an improvement to a system comes out of accumulated surplus or depreciation reserves, the selection of an interest rate for analysis is largely academic and sometimes is not given the thought it deserves.

Often, where a low municipal bond interest rate is possible and is used as the basis in the analysis, a higher investment may be indicated as achiev-

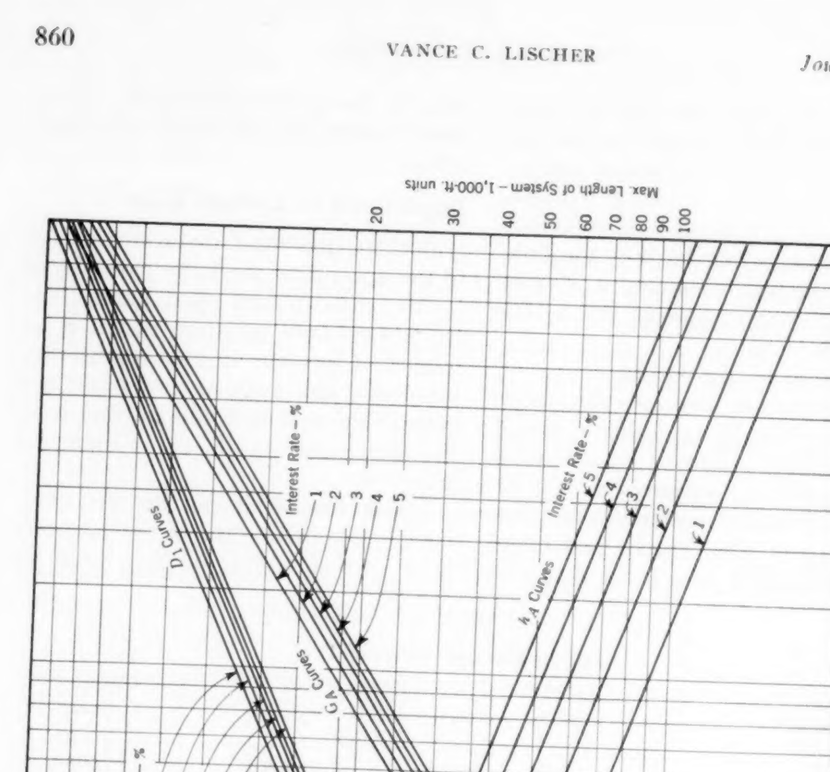

FIG. 4. Relationships of Distribution System Variables

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ing the most economical solution of the problem. Perhaps, then, the use of the borrowing rate in the analysis may not in the long run be to the best advantage of the consumer, who ultimately pays the cost. The money used to finance the project, whether obtained from accumulated earnings or borrowed at current interest rates and later repaid, comes out of the consumer's pocket. Certainly, the value of the money to him is pertinent to the problem.

Effect of System Length

Although the capacity of any system is unlimited, depending only upon the amount of pressure that can be impressed upon it, it is obvious, from a practical standpoint, that an upper limit of pressure must be established for water works practice where customers are being supplied along the transmission mains. In this connection it should be noted that the economical diameter is independent of the length of the system (except to the extent that more costly higher pressure pipe might have to be used).

If booster pumps are not employed in the system to restore energy lost by friction, and if elevated storage is not used for equalizing pumping rates, a maximum limit of system length will be indicated for any assumed maximum plant or pumping pressure. This limit, in turn, is dependent on the average daily pumpage, the rate of interest assumed and, of course, on all the other variables in the problem.

In Fig. 4, horizontal lines are shown which relate to the series of curves (h_A) giving the loss of head at the average pumping rate. These lines show the upper limit of length that the conditions could meet where no storage for equalizing high service rates is used and where the upper limit of pumping pressure is 125 psi. This is not an unreasonable upper limit and can be met by Class 150 pipe. It is based on maintaining an acceptable operating pressure of 50 psi. at the end of the system, with an allowance of 75 psi. for the maximum friction loss.

If longer transmission systems were required than those indicated in Fig. 4, elevated storage or booster pumps would be necessary. It is significant that the lengths of systems indicated are commensurate with those which might be encountered in an actual system supplying the average daily consumption indicated.

Significance of Elevated Storage

As pointed out previously, one of the functions of elevated storage is to equalize pumping rates. Equalizing storage can serve: (1) to reduce the amount of installed pumping capacity, (2) to reduce the amount of power facilities to be reserved for pumping (this may be reflected in the power rate as demand charge if purchased power is used), (3) to make possible the attainment of higher pumping efficiency by reducing pressure extremes and (4) to permit savings in transmission mains.

As stated before, some amount of storage is needed to minimize purification plant investment. Ground or elevated storage may be used. If ground storage is employed at the site of the plant and there is no elevated storage, pumpage must keep pace with demand. If elevated storage is used, it is often made adequate for equalizing the rate on the maximum day. Assuming that

at least enough storage to equalize the maximum day's pumpage can be justified for reducing purification plant capacity to a satisfactory minimum, it is only necessary to consider the incremental cost for making this storage elevated in analyzing its effect on the economical diameter.

It has been shown that the duration curve of pumping rates (Fig. 2 and 3) introduces a factor K of 1.35 in the equation for the economical diameter (Eq. 10). Using the amount of elevated storage often considered desirable—that is, the amount necessary to equalize the demand on the maximum day—it can be shown that no significant change is made in the investment in mains because of the influence of factor K alone.

The amount of storage required to equalize the pumping rate on the maximum day might be on the order of 15 per cent of the maximum daily pumpage. Assuming that the maximum day's pumpage is 160 per cent of the average daily pumpage, the amount of equalizing storage would be approximately 24 per cent of the average daily pumpage. With the maximum pumping rate limited to 160 per cent of the average daily pumpage, as it would be with this amount of storage, K might be reduced to 1.15. This reduction in K would reduce the cost of economical mains only 2 per cent.

Although the change in the K value affects the economical diameters insignificantly, the changed cost in pumping facilities has an important bearing on the problem. In the absence of elevated storage, pumping facilities must be provided for the maximum hourly demand. Thus, as shown in the development of the equation for the cost of pumping, a station with a total capacity of 310 per cent of the average daily pumpage is required where no equalizing elevated storage is provided; by comparison, a capacity of 213 per cent of the average is needed where elevated storage is included. A further cost difference results from the fact that a higher maximum pumping pressure must be provided for without elevated storage.

Introducing these changes into the equation for the incremental cost of pumping facilities (Eq. 5a), a new equation is obtained:

$$\text{Incremental Cost} = 77Qh.$$

This equation changes the constant T from 882 to 521, using 3 per cent

TABLE 4

Interest Rate and Values of h_A, D_1 *and* G_A

Variable	Interest Rate—*per cent*				
	1	2	3	4	5
h_A	$\frac{0.934}{Q^{0.366}}$	$\frac{1.17}{Q^{0.366}}$	$\frac{1.40}{Q^{0.366}}$	$\frac{1.62}{Q^{0.366}}$	$\frac{1.83}{Q^{0.366}}$
D_1	$12.10\ Q^{0.455}$	$11.55\ Q^{0.455}$	$11.13\ Q^{0.455}$	$10.80\ Q^{0.455}$	$10.54\ Q^{0.455}$
G_A	$4{,}824\ Q^{0.637}$	$4{,}524\ Q^{0.637}$	$4{,}293\ Q^{0.637}$	$4{,}116\ Q^{0.637}$	$3{,}979\ Q^{0.637}$

interest, $K = 1.15$, $P = \$0.007$, $E = 75$ per cent and $C = 130$. The constant in the equation for the cost of mains is reduced from 4,293 to about 3,820, a cost reduction of about 12 per cent.

Examples are listed in Table 6 for systems with and without elevated storage, giving the total first cost of various units. Storage (24 per cent of the average daily pumpage) for equalizing the pumpage on the maximum day is assumed and its cost—as elevated in lieu of ground storage—is taken as 10¢ per gallon. The values in the table are based on an interest rate of 3 per cent, $P = \$0.007$, $E = 0.75$ and $C = 130$. The differential costs of the pumping stations are probably higher than they would actually be because only the size, and not the number, of the units would be affected.

Table 6 does not give the complete costs for transmission mains. There are other secondary feeders, and their costs, which should be included, would reduce the savings indicated for systems without storage. It is even possible that the inclusion of the costs of these mains might make systems with storage comparatively less costly. Undoubtedly, the minimum operating cost would be obtained with some lesser amount of storage than that necessary to equalize the pumpage on the maximum day. Savings possible through the improved load factor brought about by the use of storage may have to be taken into account.

It should be noted that the quantity of elevated storage required for equalizing purposes to reduce the amount of pumping facilities is determinable basically from the duration curve of pumpage. This curve is independent of the length of the system. Therefore, in compact systems, where smaller investments in transmission mains are required, the savings in mains will be less and smaller amounts of equalizing storage can be justified.

TABLE 5

Comparison of Theoretical and Commercial Main Sizes

Main From Pumping Sta.	Theoretical Diameter *in.*	Commercial Sizes		
		Diameter *in.*	Cost per 1,000 ft. $	Loss of Head at Q, per 1,000 ft. *ft.*
1st	43.5	42	37,000	0.74
2nd	42.1	42	37,000	0.61
3rd	40.7	42	37,000	0.49
4th	39.1	36	30,000	0.81
5th	37.4	36	30,000	0.61
6th	35.5	36	30,000	0.44
7th	33.2	36	30,000	0.29
8th	30.5	30	23,000	0.41
9th	27.1	30	23,000	0.20
10th	22.1	24	17,000	0.16
	$h_A = 0.471$ $G_A = \$29{,}000$	*Average*	\$29,400 (G_A)	0.476 (h_A)

In systems where the demand for water is subject to greater variation than is assumed in this problem, storage may be required to limit the maximum pumping pressure during the peak hour. The alternatives to the use of storage for this purpose are booster pumps or separate consumer supply lines along the transmission mains where pressures are too high for serving consumers. These possibilities deserve consideration in an economic study.

In a particular problem, where all the costs could be set up, it should be possible to determine the most economical combination of mains and storage. The purpose of this paper is essentially to describe the method of analysis.

Pumping Station Design

If the economic analysis indicates that little or no equalizing elevated storage can be justified, careful attention must be given to the design of the pumping facilites to meet the requirements existing under these conditions.

TABLE 6

Initial Costs of Distribution System Units

Unit	Average Pumpage			
	10 mgd. (30,000-ft. Length of System)		20 mgd. (40,000-ft. Length of System)	
	With Storage	Without Storage	With Storage	Without Storage
Dual Supply Mains				
Mains	\$640,000	\$720,000	\$1,330,000	\$1,500,000
Pumping Station*	100,000	160,000	200,000	320,000
Elevated Storage	250,000		500,000	
	\$990,000	\$880,000	\$2,030,000	\$1,820,000
Single Supply Main				
Mains	\$500,000	\$560,000	\$1,030,000	\$1,160,000
Pumping Station*	95,000	145,000	195,000	295,000
Elevated Storage	250,000		500,000	
	\$845,000	\$705,000	\$1,725,000	\$1,455,000

* Pumping station costs are obtained from the following equations:
With Storage: Cost $= 64QH_1 + 77Qh$
Without Storage: Cost $= 93QH_1 + 220Qh$

The station required in a direct pumping system without storage must meet water demand variations over a range of 7.7 to 1 with a demand curve similar to Fig. 1 and pressure variations from 204 to 117 ft. This statement is based upon the 20-mgd. single main system analyzed in Table 6 as a

representative example. Under some conditions, even greater pressure variations may be indicated. A different duration curve of pumpage would result in different ranges of flow and pressure which the design must take into account.

The modern electrically driven centrifugal pump cannot meet these wide extremes and deliver a high average operating efficiency. It would be possible for a station to be designed to meet the varying requirements with good efficiency, but the utilization of such a design in the problem would require that the greater cost be reflected in determining the economical sizes of mains.

The means for meeting the extreme variations in the design might include the use of two-stage pumps, with provision for single-stage operation during the low-pressure periods. Careful determination of pump sizes would be necessary to permit coverage of the entire head-capacity requirements with variable speed applied only to a small part of the load.

Another method of effecting a high degree of flexibility would be to make use of the stand-by power facilities, which would ordinarily be required in a system supplied with purchased power. If these power facilities consisted of diesel engines, they could be used to drive the second-stage units to obtain the high pressures required during peak demand. From the pressure range given above (117–204 ft.), and the duration curve of pumpage in Fig. 1, it is apparent that the pumping head will be in excess of 150 ft. only about 10 per cent of the time. The range of head from 117 to 150 ft., with the average approximately 135 ft., could be handled by a single-stage pump with good efficiency. The utilization of a small amount of diesel pumping at all times, to cushion the variation in demand and permit the electrical units to operate at full speed, would be highly beneficial in reducing electrical demand charges and in improving the average station efficiency.

It can be seen, from the equation for the economical diameter, that the capital cost in pumping station facilities is an important element, particularly because a large capacity is required in a direct pumping system. The costs are based on conventional pumping station design with indoor installations and all of the auxiliary expense which accompanies the substantial construction used in municipal practice. With the advent of the outdoor unit substation and the outdoor vertical pumping installation, unit costs of pumping stations should be materially reduced. With this reduction in cost, it may be shown that there is less justification for large amounts of equalizing elevated storage.

Present Practice

It should be apparent that present practice departs far from the attainment of maximum economy for two basic reasons. One is that losses of head and velocities in use in existing systems are in general lower than those indicated for the economical pipe sizes in these studies. The other and more important reason is that the method of operation of systems with storage results in the waste of energy.

In systems where elevated storage is employed, it is customary to operate with the storage floating on the line, or even with the pressure sufficiently

high to keep the altitude valve closed. If the storage is designed to provide adequate pressure when needed, all of the storage should be above the gradient necessary for supplying the normal requirements. Storage for equalizing purposes is used when the demand for water is greatest. If this storage is floating on the system, it can be made available only by allowing the pressure to fall in the areas served by it. The pumping facilities, mains and storage are therefore designed to maintain an adequate pressure for the most remote customer *at the peak,* and the inherent design of the system results in greater than adequate pressures being maintained most of the time.

For systems with storage floating on the line, a pressure drop of 20–30 ft. may be necessary to make it all available. This may be 15 to 20 per cent of the entire pumping head and may represent that same proportion of the total power cost.

In order to function in a manner conducive to the greatest economy, the elevated storage designed to be available above the normal gradient would be refilled either by means of booster pumps or by raising the entire system pressure only during a relatively short period of filling at night. The tank would remain shut off until the equalizing storage is required. It should then be supplied to the system by means of a pressure-reducing valve which would supply water only as the demand made necessary. Such a means of operation would require a different method of controlling the tank than the ordinary altitude valve provides. The most efficient operation would be by remote control, which might not be economically feasible. A timing device in conjunction with a pressure reducing valve might, however, be satisfactory.

The entire job of serving the water pressure requirements in a large community calls for centralized control. Such a center should have pressure indications from critical points in the distribution system, as well as the elevations of water in all storage tanks and reservoirs, and should also be informed of the pumping rates at all pumping stations. At such a center, controls could be provided for placing on the line the storage from any elevated tank when it is most needed and for conserving it at other times.

Conclusions

1. The problem of the determination of economical main sizes, storage and pumping facilities is amenable to analysis.

2. The losses of head in the economical main sizes do not result in unreasonably high pumping pressures in systems in flat terrain.

3. The value placed on money for capital investments has an important bearing on the economical diameter and on the total investment required. The effect of different assumed interest rates is so great that engineers should concern themselves with the basic factors influencing the choice of an interest rate for economic studies and should develop a rational method for selecting that rate.

4. It cannot be categorically stated that elevated storage for equalizing purposes to reduce main and pumping station costs in systems in flat terrain can be justified. Such justification depends upon the length of the system,

in addition to the other variables in the problem.

5. The design of pumping facilities for a system with economical mains and without elevated storage presents some problems which should stimulate pump designers to improve the flexibility and range of operation of centrifugal pumps.

6. A reduction in the cost of pumping facilities, such as might be possible by the use of outdoor pumping units and substations, will minimize the amount of elevated storage which can be justified for equalizing purposes.

7. The usual method of operation of systems, in which elevated storage floats on the line, is wasteful of energy.

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A Theory of the Functioning of Filters

By H. E. Hudson Jr.

A contribution to the Journal by H. E. Hudson Jr., Head, Eng. Subdiv., State Water Survey Div., Urbana, Ill.

In recent years there have been several very prominent trends in rapid sand filtration practice: the use of coarser sand; the improvement of coagulating processes and facilities; and the use of reduced settling times, together with improved inlet and outlet design. These trends, properly coordinated, can do much to decrease plant construction cost, increase capacity and produce better water. Sometimes, however, not enough thought is given to the relationships between the quality of water applied to the filter and its design and function. These relationships are particularly critical in the recently developed high-rate treatment plants and in some older plants that are overloaded.

It is the purpose of this paper to outline a rational theory covering the functioning of the rapid sand filter. Certain ideas resulting from this theory make possible a more concrete comparison of the results at various plants. Using the theory, one can more clearly understand some of the difficulties encountered and the limitations that exist in filtration plant design and operation. The theory is presented in its simplest form so that it may be easily employed.

Rapid Sand Filter Runs

One may assume a rapid sand filter of unit area having a depth l of filter medium. The rate of filtration may be denoted by Q, the volume of water filtered per unit of area per unit of time. Other relevant symbols may be identified as:

c —the concentration of suspended matter in the applied water, expressed in weight per volume of water
l_1—the depth to which suspended matter penetrates into the filter
h —the loss of head through the filter medium
h_1—the increased loss in head, caused by filter clogging
p —the ratio of void space to the volume of the filter medium
d —the density of the suspended matter in the water
T—time
m—the "effective size" of the particles in the filter medium
v —the velocity of flow

In a sand filter at ordinary flow rates:

$$h = KQl$$

in which K is a constant. The volume available for the retention of suspended matter per unit of filter area will be l_1p. The volume of suspended matter applied to the filter will be $\frac{QTc}{d}$. For complete removal, the proportion of the available retention volume filled by suspended mat-

→d = THE WEIGHT OF SUSPENDED MATTER/UNIT VOLUME, AS TRAPPED IN THE FILTER

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ter in time T will then be $\frac{QTc}{dl_1p}$. The space occupied by this volume will not permit the passage of water, and the flow Q will have to pass through a restricted cross section of area $1 - \frac{QTc}{dl_1p}$. The rate of flow through the unclogged area will therefore be equivalent in velocity to a higher rate of flow through a clean filter:

$$Q_1 = \frac{Q}{1 - \frac{QTc}{dl_1p}}$$

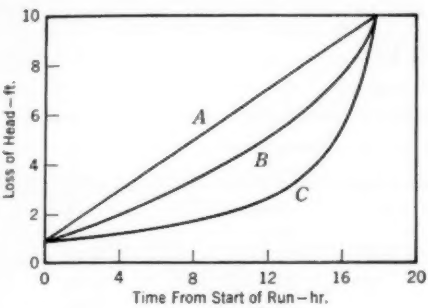

FIG. 1. Filter Run Data

The loss of head through the clogged portion of the filter will be:

$$h_1 = \frac{KQl_1}{1 - \frac{QTc}{dl_1p}}$$

The total loss of head through the filter bed will be:

$$h = KQ(l - l_1) + \frac{KQl_1}{1 - \frac{QTc}{dl_1p}}$$

In practice the density d varies somewhat during the filter run. The density of the suspended matter applied to the filter is usually close to unity. During the filter run this value may rise, because of the compression of the suspended matter, to a maximum of 1.3, according to actual measurements (1). Hence d may be considered as a constant without introducing any large error.

As a rule, the suspended matter concentration c in the applied water is uniform, and, of course, p is very nearly constant for clean sand. The rate of filtration Q is kept constant mechanically in municipal practice.

The value of the constant K is determined from the initial loss of head. This constant is the reciprocal of the coefficient of permeability.

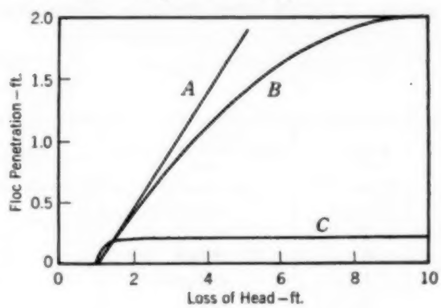

FIG. 2. Penetration of Floc

This discussion leaves one principal unknown, l_1, the depth of penetration of the suspended matter into the filter. This value may vary throughout the filter run, and its behavior must be established experimentally, either by calculation from loss-of-head data or by measurement of the floc penetration.

The process of sand filtration has been carefully described by Baylis (2). The theory set forth in the present article has been conceived in accordance with his description.

Eliassen carried on valuable experiments along the same line at Providence, R.I., and some of his data have been published (3). They clearly re-

veal the increasing penetration of floc into the filter medium as the run progresses. Similar observations have been reported by Georgia (4).

Calculations of floc penetration depths from loss of head data for three characteristic filter run curves have been made. The filter run curves are shown in Fig. 1 and the penetration data in Fig. 2. Curves *A* are for relatively weak floc, *B* for more nearly adequate floc strength and *C* for strong floc.

The reasoning given above and the curves shown lead to two generalizations: (1) A straight-line filter run curve is indicative of increasing penetration of floc into the filter medium. If continued long enough, floc may appear in the filtrate. (2) A filter run curve having a marked upward curvature is indicative of limited penetration of coagulated matter into the filter medium. This is the normal condition.

Floc Strength Index

A particle of floc bridging a pore in a filter has to withstand the pressure of the water flowing through the filter. The pressure on the particle will be indicated by the filter hydraulic gradient. The strength of the particle may be expected to be a function of the largest size of pore it will block.

Pore size in a filter medium of particulate material is closely related to the diameter of the particles. For media of similar porosity, containing similarly shaped particles, the study can be confined to the effect of particle size alone. The analysis can readily be extended to include the effects of porosity and particle shape by the method of Fair and Hatch (5).

A study of published data (6) indicates a clear-cut relationship between the particle size and the loss of head at which the floc passes through the filter bed. The data on which this relationship is based are for filter media of relatively rounded sand of different effective sizes, operated in parallel, so that all received water containing floc of equal strength. These data indicate that, for a given water, $\frac{hm^3}{l}$ is a constant when h is the loss of head at which the floc begins to pass through a bed of depth l. This constant may be called the floc strength index.

Table 1 shows the calculated floc strength indexes for a series of glass

TABLE 1

Floc Strength Indexes

Filter No.	Effective Size of Sand *mm.*	Bed Depth *ft.*	Loss of Head *ft.*	$\frac{hm^3}{l}$
1	0.515	2	2.06	0.14
2	0.307	2	10+	0.14+
3	0.568	2	1.91	0.18
4	0.400	2.5	10+(?)	0.26
5	0.422	2	6.15	0.23
6	0.430	1.5	4.15	0.22
7	0.490	2*	2.94	0.17

* Estimate.

tube filters operated in parallel during a period of weak coagulation (6). No floc passed through filters No. 2 and 4 during most of these tests, so the data for these units are unreliable. Fair agreement was obtained for the floc strength indexes of the others.

Table 2 shows the floc strength indexes for four filters containing uniform sands, operated during another period of weak flocculation. Results for filter No. 1 do not compare well with those for the other three units, probably because some of the pores through the former unit were larger than the floc particles.

Similar data were collected for a set of four filters containing sand of an identical size but of various depths, operated at the same rates. No floc passed through the two deepest units, as shown in Table 3.

The tables have oversimplified the true picture somewhat, for, in actual practice, few filters are composed of uniform materials. The penetration of the floc through the top few inches of the filter brings it in contact with coarser material that allows easier passage.

Most of the floc strength indexes calculated are for very weak flocculation, since they are based on the actual passage of the floc through the filter. Ordinarily, at an 8-ft. loss of head, the floc penetration is relatively small—less than 2 in. These values indicate a floc strength index of the order of 5.0 or more.

Certain interesting comparisons can be made on the basis of this analysis. For example, three filter beds having sand sizes as given below would have to have very different pretreatments to produce water of equal quality. The necessary floc strength indexes to obtain clear water at an 8-ft. loss of head, with a 2-ft. bed depth, are: 0.256 for an effective sand size of 0.4 mm.; 0.50 for a sand size of 0.5 mm.; and 1.10 for a sand size of 0.65 mm.

When the floc is so weak that it is difficult to produce clear water by filtration, there are two ways out: either to terminate the filter runs at a lower head loss or to strengthen the floc. The former is the usual resort, but data obtained by Baylis (7) indicate that silica treatment increased the floc strength index at least sixfold. For the sand sizes listed above this would have enabled the coarsest to perform as well as the finest.

TABLE 2

Floc Strength Indexes

Filter No.	Effective Size *mm.*	Bed Depth *ft.*	Loss of Head *ft.*	$\frac{hm^2}{l}$
1	2.39	3.0	0.17	1.14
2	1.74	2.0	0.75	1.99
3	1.0	2.0	4.1	2.05
4	0.85	2.0	7.1	2.17

Diatomite Filters

The principles outlined in this paper may be applied to diatomite filters as well as to sand filters. To a limited extent, this is borne out in some wartime work in which the author was

involved (8). The chief differences between diatomite and sand filtrations lie in the particle size and bed thickness. Diatomite filter beds may be of the order of 0.1 in. in thickness. The diatomite particles are very fine: the permeability of a filter of the coarsest diatomaceous silica is approximately one-hundredth that of a filter of 0.5-mm. sand. On this basis, the diatomite particles have diameters (calculated as equivalent spheres) of approximately 0.05 mm. More generally available diatomite has an equivalent particle diameter of 0.025 mm.

TABLE 3

*Effect of Bed Depth on Passage of Floc**

Filter No.	Bed Depth *ft.*	Loss of Head *ft.*	$\frac{hm^2}{l}$
1	3	9+	0.38+
2	2	9+	0.56+
3	1	8.6	1.08
4	0.5	4.2	1.05

* Sand size 0.5 mm.

Baylis (2) has shown that filter runs vary approximately with the second power of the particle size. Diatomite filters operated like sand filters should therefore be expected to give filter runs about one-hundredth as long as sand filters. This is overcome by: (1) the operation of the diatomite filters at greater head losses; (2) better pretreatment of the water to reduce the clogging rate; and (3) the use of continuous diatomite slurry feed to reduce the clogging rate.

One of the principal advantages of the diatomite filter over the sand filter is its ability to prevent the passage of flocculated matter. A conventional sand filter 2 ft. thick and containing 0.5-mm. sand will pass floc at an 8-ft. loss of head when the floc strength index falls below 0.25; however, a bed of 0.05-mm. diatomite 0.1 in. thick would not permit the passage of such floc until the loss of head reached 16 ft.

At times when weak flocculation endangers the quality of the filter effluent, filter runs are usually long. The threat to water quality may be overcome by using (1) thicker diatomite beds, (2) continuous slurry feed or (3) finer diatomite.

Acknowledgments

The author acquired the basic experience in the light of which this paper has been written under John R. Baylis, Engineer of Water Purification, Chicago. Max Suter of the Illinois State Water Survey Div. reviewed the article and made constructive comments.

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Prevention of Underground Leakage

By Loren E. Blakeley and Victor A. Endersby

A paper presented on May 4, 1948, at the Annual Conference, Atlantic City, N.J., by Loren E. Blakeley, Cons. Engr., Santa Ana Valley Irrigation Co., Orange, Calif., and Victor A. Endersby, Engr. in Charge, Asphalt Dept., Shell Development Co., Emeryville, Calif.

THE water problems of California date from its early history. Because of the complex gridwork of earth and cross faults which created the many basins and river systems of the area, the intermittent, scanty rainfall was stored in vast underground reservoirs, over the lips of which flowed rising streams. The first diversions of these streams took place about 1775. Some 40 years later small rubble masonry dams were built in canyons cut through alluvial material to raise the ground water level and obtain water power for grist mills. Ground water thus salvaged and controlled was conducted in ditches, some lined with burned clay tile, to farm lands several miles from the source.

After the Mexican War water development became more rapid. Earth canals, nearly all of which have since been lined with cement, were built along the foothill and valley land. The surface water thus diverted was inadequate in quantity and regularity for sustained agricultural development. About 75 years ago it was found that tunnels could be driven through the fault zones generally defining the mountain faces and the boundaries of the major underground water basins. These tunnels usually passed through somewhat shattered granite to tap the water stored in the base of the mountains and to reach bedrock in the bottom of gravel-filled mountain canyons. Several submerged dams of cement concrete were built to salvage this high-elevation ground water. The shattered nature of the bedrock made many such structures uneconomical, and much valuable water passed on underground. Some tunnels were driven through 1½–3 ft. of nearly vertical seams of clay gouge or "slickens" in alluvial conglomerate, along which vertical and lateral movement up to 1,200 ft. is indicated. Such tunnels have tapped ground water over 30 ft. below the surface and were quite productive until the lowering of the water table in the basin drained the water stored there.

With increased urban and agricultural development, most of the readily available surface and rising underground water was put to use; wells were drilled and pumps were installed to divert the slow travel oceanward of stored underground water. In strategic locations flowing artesian wells were sunk, some developing pressure heads up to 40 ft. A few such wells are still flowing, but most basins in the southern California area are overdrawn. This has resulted in a leveling off of the water table, with persistent depression cones around zones of heavy pumping; and underflow actually in

reverse of surface drainage has sometimes occurred. Overdrawn ground water basins are inexorably pulling salt water through gravel strata in the Continental Shelf toward the deep alluvium-filled basins which are the sole present source of water supply for about a million people.

Santa Ana River

The Santa Ana River is the principal stream on the coastal plain of southern California. Approximately 90 per cent of its average annual yield of 270,000 acre-ft., including percolation from rainfall, is utilized (1). The watershed which furnishes water to the coastal plain comprises some 1,400 square miles of steep mountain and sloping inland basin floors. Storm water from this area is slowed down by the Prado Flood Control Reservoir, and rising surface water passes the dam throughout the year and is diverted by the Anaheim Union Water Co. and the Santa Ana Valley Irrigation Co. Below the earthwork intake dam of the latter company, a rank growth of tules and other water-loving vegetation, covering some 10 acres of river bottom land, has existed for more than 70 years, indicating a very substantial loss of water by seepage beneath and around the dam. Wells below the dam have been recovering some of this water, but much was definitely lost, partly as a result of transpiration by this useless plant life.

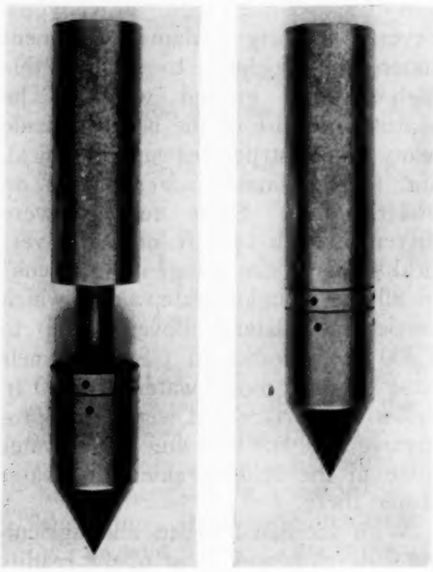

FIG. 1. Special Injector Driving Point

Various means of salvaging the loss have been proposed and discarded. Because of flood hazards and previous losses by the company and others in the narrow canyon bottom, it did not appear wise to drill more wells in the vicinity of the intake. The use of bentonite clay, cement grout, salt-silicate treatment (2) and plastics (3) was considered but all of these were found to be unsuitable for the conditions encountered.

An unprecedented flood in March 1938 swept out the earth diversion dam of the Santa Ana Valley Irrigation Co., and in two hours a sudden peak flow of approximately 100,000 cfs. removed a clay and gravel deposit more than 20 ft. deep from a sandstone reef just upstream from the dam. Geologists have determined this older, now practically dry, formation to be the Topanga Formation of the Miocene Age (4). The sandstone and shale bedrock, which stands vertically because of the heavily faulted condition of the area, probably is lower Eocene and is much older. Recent unconsolidated alluvium lies on top of the sandstone bedrock for a distance of nearly 3,000 ft. across the bed of the canyon. Well logs indicate an average depth of approximately 50 ft., although the maxi-

mum depth at the dam is about 30 ft. It is from this alluvial material that recoverable water is derived.

In December 1945 the Shellperm process of impermeabilizing formations against the underground flow of water by the injection of a special asphalt emulsion was called to the attention of a California statewide water council at Sacramento. Preliminary study showed that this process held potentialities of interest to the water companies in the Santa Ana region for the recovery of wasted water and the reduction of pumping costs in the coastal basin and narrow canyon below the canal intake just described.

Accordingly, a preliminary investigation of the dam site was made in May 1947, which determined that the material to be encountered and the depth to bedrock were quite favorable from the application viewpoint. As a result, equipment and materials were assembled and the injection work was undertaken in September 1947.

In passing, it is of interest to note that the expectations of successfully applying the Shellperm process were strengthened not only by evidence of considerable use of the process abroad in connection with water shutoff problems of various kinds, but also by a local observation that, at several points on top of the sandstone reef near the dam, gravel from old watercourses was cemented to the bedrock by ancient seeps of petroleum. This hard, dry material had formed an impervious conglomerate which withstood the flood peak and helped divert the storm water back into the normal river channel.

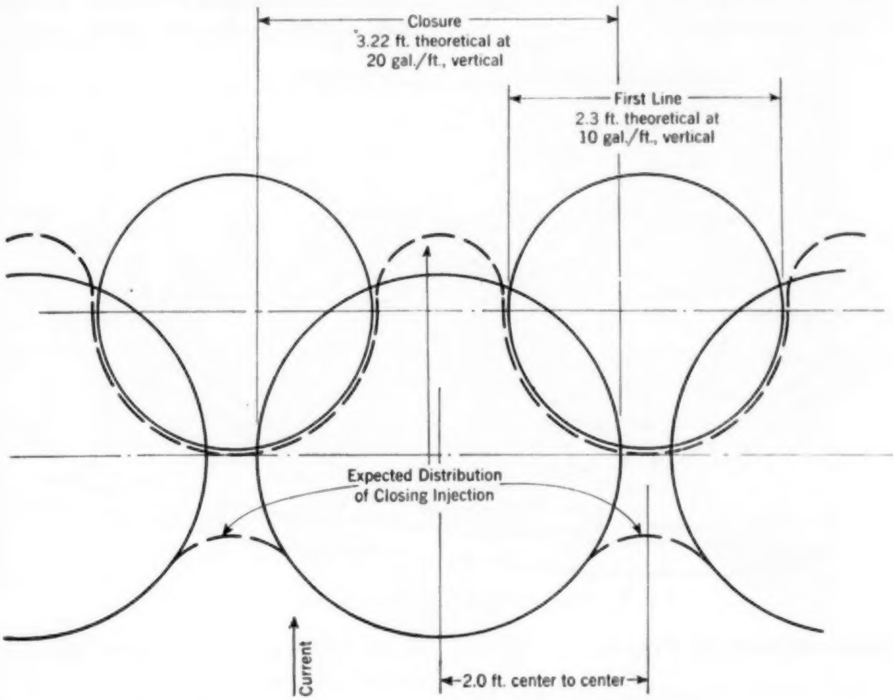

FIG. 2. Injection Scheme at Intake Dam

The results of the application of the Shellperm process were most gratify-

ing. As in all development work (this was the first application of the process in America) numerous problems were encountered, but a satisfactory shutoff of water formerly passing through the gravels under the dam was accomplished. This paper will present the principles of the process, the method of its application in the Santa Ana Valley, the results achieved in terms of water saved (as estimated from hydrologic studies) and a brief outline of other applications.

underground sands in bodies of controlled form and location, and of a consistency somewhat approaching that of the asphaltic binder in a city pavement.

Unless expensive heating methods are used, asphalt cannot be injected into sand in the form of paving grade; it is also difficult to inject it in the form of road oil or cutback, both of which, moreover, are likely to have too unstable a structure to resist viscous displacement from the sand pores.

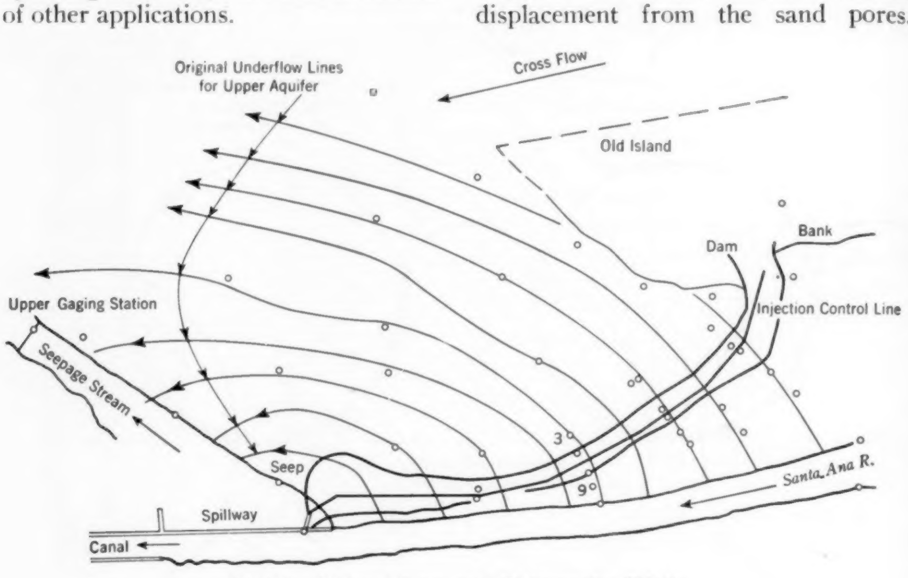

FIG. 3. Plan of Dam and Observation Wells

Chemical Basis of Process

Most civil engineers are familiar with the use of asphalts in road work —in the form of paving grades applied hot, of cutbacks and road oils applied at moderate temperatures and of emulsions applied cold. The base material is the high-molecular-weight hydrocarbon residue from the distillation of petroleum and is of very complex and as yet undetermined molecular structure. The principle of the Shellperm technique * is to get this material into

Thus, although very light specially treated oils may sometimes be used in denser soils, in general the success of the process has been due to the use of emulsions.

An emulsion of this nature consists of fine particles of asphalt suspended in water in a colloidal condition. There are several differences between the Shellperm emulsions and normal road and industrial types. Usually the particle size in the former is much smaller. Furthermore, road emulsions are designed to break or coagulate upon the evaporation of the aqueous

* Process patented.

phase, but the Shellperm emulsions, not being exposed to air, must be coagulated by special chemicals. At the same time they must be protected against surface break at contact with the soil by means of special stabilizers.

Asphaltic emulsions are often formed by shearing the asphalt under high stress in a colloid mill, in the presence of water containing surface-active polar agents which form a protective film around each particle, preventing it from coagulation with its neighbors. In the Shellperm process, the emulsion is coagulated in part by the removal of this film by the surface action of the sand particles as the emulsion passes through, and in part by the reaction between a coagulant or "breaker," the surface film and the water. This breaker is mixed with the emulsion before injection, obviating the nuisance of a two-fluid injection.

Essentially, then, the process involves the injection of a fine-grained emulsion of low viscosity (approaching that of water) into sand, using a chemical means of controlled coagulation in the absence of air. The rate of coagulation is part of the art of application; if too rapid, insufficient emulsion will be injected at a given point before the pumping resistance becomes too great; if too slow, the emulsion may be seriously displaced by underground flow, where present.

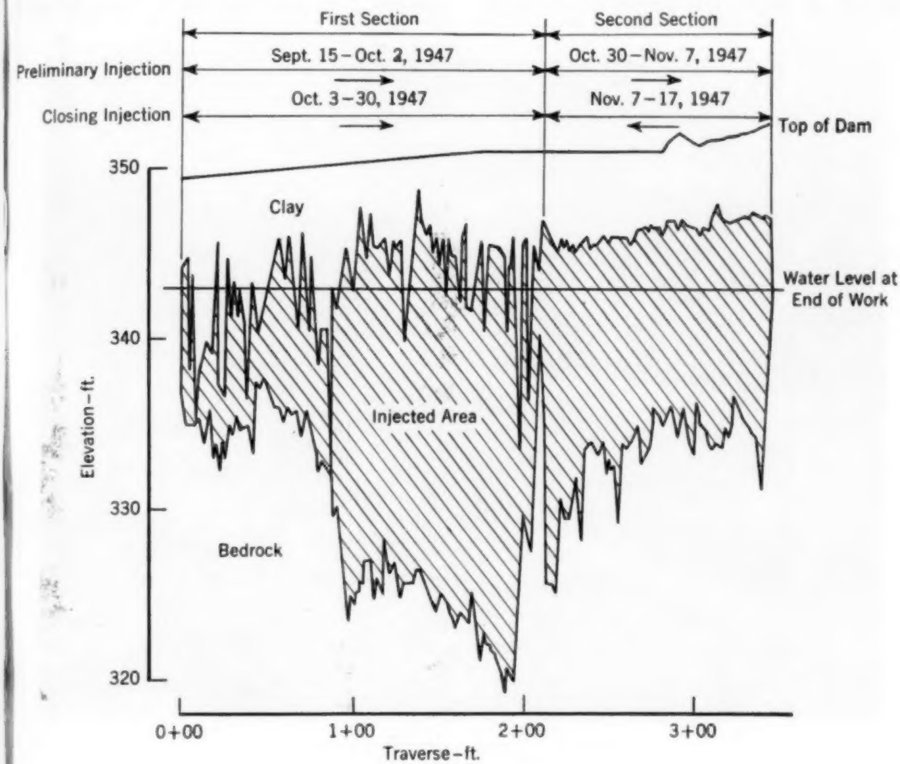

FIG. 4. Profile of Dam and Shellperm Barrier

While the method plasticizes the sand and adds considerable cohesion,

it is not intended in the usual form as a mechanical solidifier, but only as a hydraulic barrier.

Injection Technique

The emulsion is injected under pressure through a driven pipe with a special point, shown in Fig. 1. This point serves as a driving shoe; when the base of the formation to be treated is reached, a slight retraction of the pipe opens the point ready for injection. As the injection proceeds, the pipe is retracted by stages. A given amount of emulsion is injected per foot of withdrawal of the pipe, the amount being determined by the voids in the soil and the diameter of the column to be formed. The completed barrier thus consists of abutting columns. It is often found advantageous to inject the barrier in alternating columns, the first line assisting to control the distribution of the emulsion in the second or closing line, and also functioning as an exploration survey which enables very close forecasts to be made of the progress and cost of the job when it is not more than half completed.

The scheme of injection employed on the Santa Ana Valley Irrigation Co. work is shown in Fig. 2. The second line of injection was placed somewhat upstream to counteract the influence of the current, which was measured at one point as more than 30 ft. per day on a gradient of 1 per cent, with original gradients of up to 4 per cent or more across the barrier site under portions of the dam.

The formations encountered, and the order and dates of injection, are shown in Fig. 3 and 4. The work was divided into two sections, so that the

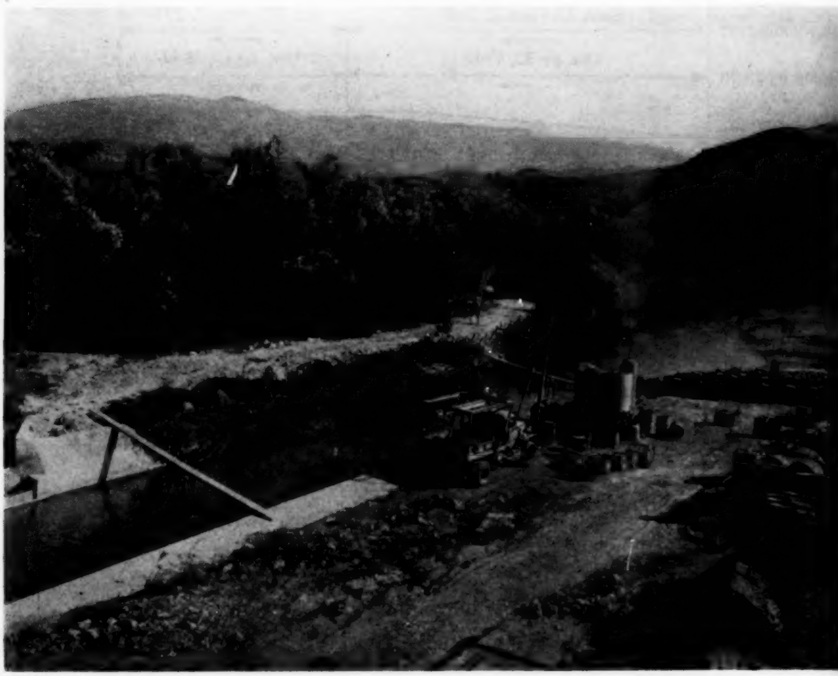

Fig. 5. Earth Diversion Dam

results of the two shutoffs could be observed separately. These sections also coincide with incidents in the history of the dam. The first section covers the deep channel washed out in the flood of 1938; the second is an older formation. The dam was rebuilt in 1938 while water was still flowing through the channel, and part of the clay fill was dumped into the water. The effect of this is evident in the irregularities in the summit of the injected stratum in the first section, as compared with the smooth line in the second.

The ground conditions could be considered somewhat difficult for pipe driving, because of the presence of boulders, roots, logs and stumps. The effect of these was to deflect the pipes rather than to delay the rate of penetration, although the maximum deflection required the injection of only a 4-ft. column in the second line instead of the normal 3-ft. diameter, for closure.

The precise placement of pipes carries a premium in materials, because the additional quantities required for oversize intervals are greater than the decreases in quantity for corresponding undersize intervals. Normally the $2\frac{3}{8}$-in.-od. pipes were driven to depths of up to 32 ft. in 15–20 minutes. The injection rate at points exceeded 300 gph., with an average of approximately 200 gph. over a working day.

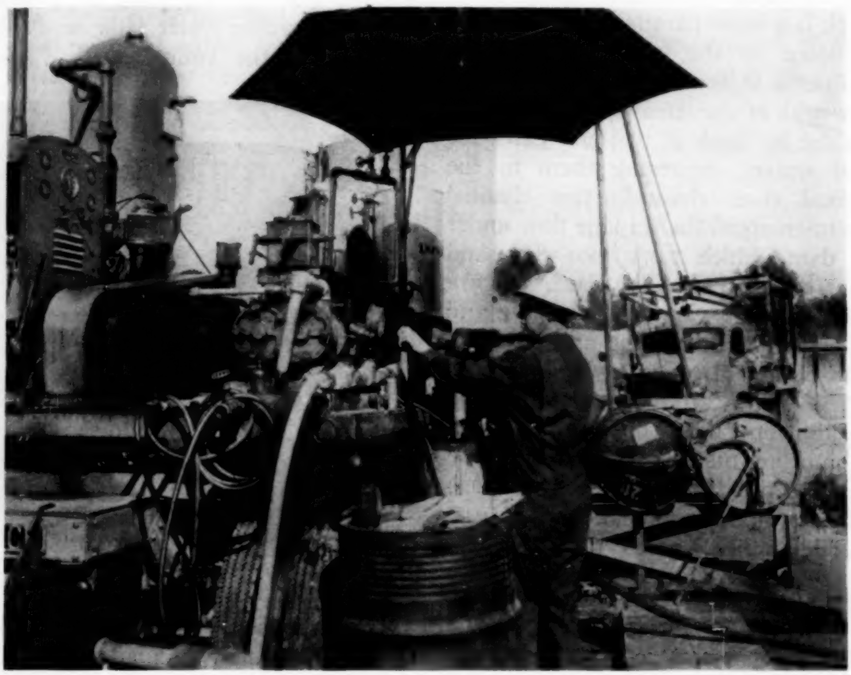

Fig. 6. Blending and Pumping Units

The crew that was found most efficient for speed consisted of a chemical engineer and assistant, and a senior technician and assistant. The work could actually be done by the two senior men alone but at a considerably slower rate. The size of the crew depends upon the number of injection

units; the supervisory overhead and total unit cost will diminish as additional units are added. The general supervision and civil engineering activities, including surveying and the gathering of hydraulic data, were carried out by one, and sometimes both, of the authors. This developmental operation naturally required more supervision than should future jobs.

Figure 5 shows the point of diversion, looking upstream. The dam, which is a levee parallel with the river, is shown on the far bank, with the Shellperm injection equipment on the near bank of the stream. The spillway (on the far bank at the left) cares for flood waters, returning them to the original river channel; this channel also intercepted the seepage flow under the dam, which sank into the sand about 800 ft. below the dam. Figure 6 is a close-up view of the supply and trailer-mounted blending and pumping units of the injection equipment, and Fig. 7 shows the pipe-driving and injection operations on the dam, with an emulsion-filled drill hole visible in the foreground.

The equipment was assembled from available units, and certain improvements—in portability, for example—can no doubt be made for future jobs.

Results

The scope of the work in Santa Ana Canyon is indicated by the statistics in Table 1. The usual average pressure ran between 20 and 30 psi. at the head of the injection pipe.

It became fairly evident during the job that underground waters were stratified by relatively impermeable layers of river-deposited material, which converged toward the lower gaging station, and that the observed regression of the stream originally flowing below the dam was due to the upper series losing support by the cutting off of water from the lower flow.

It was found that the Shellperm barrier in some places did not reach the maximum water level. Thus, at high water levels which occurred toward the end of the operation, some flow of water continued over the barrier. The major part of this was traced to a location at about the center of the first section. Approximate calculations indicated that the untreated area below the late October water table was quite small. As the equipment had been

Fig. 7. Injection Operations

removed before the surveys were finished, no attempt was made at the time to complete this area, the water saving already being much in excess of what had been anticipated. In fact, observations made on February 3, 1948, when the flow was compared with similar conditions in 1947, indicated a shutoff of about 1.0 acre-ft., based on surface runoff at a point 800 ft. below the dam. Because of the rising water table and the increase in flow from winter rains, together with the release of water by other users upstream, a more accurate estimate of the saving

in water cannot be obtained until October 1948.

Underflow Tests

A number of tests to determine the velocity of underflow were run to check the theoretical calculations, which were based on ground water elevations. Fluorescein dye was used both in shallow surface pits and in perforated test pipes, which were driven to bedrock near the deepest part of the dam. The most outstanding information gained from these tests was that the slugs of dyed ground water traveled downstream in very narrow bands, probably influenced by laminar flow conditions in the gravels. This phenomenon deserves more research than was possible on the job, in view of the apparent lack of blending of the underground waters. The velocity of dye travel in the deepest part of the gravel was found to be 31 ft. per day, as compared with 12–15 ft. in different locations in surface pits. After the completion of the job, the dye test was repeated in March 1948 at observation well No. 9. No dye was picked up at pit No. 3 and the contiguous trench below the barrier, although ground water was then standing more than a foot above the top of the barrier.

A number of tests were run with a special conductivity cell in the perforated test pipes, using a salt solution introduced into the upstream pipe. In these tests it was impossible to pick up any indication of salt in the lower holes either before or after the installation of the asphalt barrier. It is likely, however, that the installation of test pipes with full-length perforations, in a quarter-circle arc a few feet downstream from a larger pipe in which salt solution could be injected at different levels, would permit the interception of the narrow slugs of salt-treated water. It would be possible to extend the underflow test method developed on the Santa Ana Valley Irrigation Co. job to determine the effectiveness of the barrier over a period of years. Such tests in a long basin shutoff wall would be a matter of economic concern where the initial treatment is limited to the thinnest possible treated barrier rather than a zone treatment, and where there is a threat of the intrusion of ocean or other nonpotable water into the protected basin (5).

TABLE 1

Data on Santa Ana Job

Item	Unit	Amount	
		Estimated	Actual
Area shut off	sq.ft.	4,858	4,894
Emulsion used	tons	52.2	75
Fluid injected	gal.	25,000	32,400
Construction time	months	1½	1¾
Water saved	acre-ft. per day	0.3–0.4	0.66+

Other Applications

The Shellperm method, employed in this job for the first time in the United States, has been applied in a wide variety of large and small projects abroad (6). These include installations in England, Holland, France, Germany, Belgium, Switzerland, Por-

tugal and Egypt. Outstanding among these was the application of Shellperm to shut off water during the construction of extensions of the great Nile River dams at Assiut and Esna in Egypt, where 653 and 478 tons, respectively, of the special asphalt emulsion were used. Of particular interest to water works engineers is a smaller job at Liége, Belgium, where Shellperm is successfully keeping contaminated ground water from infiltrating into a potable water line. The expanded use of the process may be anticipated wherever it offers economic advantages over other construction methods.

Fundamentally, it appears that any saturated material from which water can be extracted by normal wells or pumping methods will yield to the injection of emulsified asphalt by the Shellperm technique. The process operates in the range between fine, relatively impermeable soils and coarse, open-textured gravels of the type into which cement can be injected. Its range can be extended somewhat in the latter direction by adding small amounts of cement, or mineral fillers such as clay. Many construction problems in which ground water difficulties cause high expense may economically be solved by impermeabilizing the worst of the adjacent formations. Other jobs may require a complete shut off of ground water. Thus, known leakage through sheet piling can be stopped, and under some conditions the need for such construction can be eliminated. It appears feasible to treat both vertical and horizontal zones by the proper spacing of drill holes and control of the injection process. When an economic need has been determined for deep shutoff walls, such as may be necessary to prevent the further infiltration of salt water into gravel-filled basins along the ocean or inland lakes, it appears entirely feasible to develop the necessary equipment to make the injection. Percolation into ground water basins from canals or waterways and reservoirs can similarly be controlled. Among other applications, present or potential, may be mentioned the prevention of seepage into underground openings, such as underpasses and tunnels; the stopping of leaks in concrete dams and reservoirs; and the formation of underground storage basins by placing cutoff walls across canyons. Of course, each job has its particular problems and must stand on its own economic merits.

It is evident from this discussion that the impermeabilization of water-bearing gravels by the controlled injection of emulsified asphalt is one of the most important developments in the long history of attempts to regulate the flow of underground waters.

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Collected Standard Specifications for Service Line Materials

Committee Report

These current specifications for certain types of service line materials are consolidated as a report from A.W.W.A. Subcommittee 7S—Service Line Materials. They are assembled for the purpose of making them easily available to the membership of the Association. These specifications are based upon the best known experience and the materials listed are intended for use under normal conditions. They are not designed for unqualified use under all conditions. The advisability of the use of the materials herein specified for any installation must be reviewed by the engineer responsible for selection of the material to be used in the particular locality concerned. Neither the Association nor its committee expresses preference for any material listed. These are not official specifications of the A.W.W.A.; they must not be referred to as such; and no authority is given or implied which would permit their use as official A.W.W.A. specification documents.

Comments should be addressed to Walter A. Peirce, Chairman, Subcommittee 7S—Service Line Materials, City Hall, Racine, Wis.

Foreword

These specifications have been assembled for the use of water departments in the purchase of the various service line materials. There is no recommendation given or implied concerning which material should be used. The selection of materials depends upon local soil conditions and the nature of the water supply. When a study of these factors indicates the preferential employment of a certain material, however, the particular specifications applicable are intended to be used in order to insure the delivery of a proper standard product.

It was not deemed feasible or expedient to formulate new specifications, since the various technical and trade associations have set up certain standards which apply. These standards are now brought together for the convenience of A.W.W.A. members. Published standards of the American Society for Testing Materials and the American Standards Assn., Federal Standard Stock Catalog specifications, data supplied by the Lead Industries Assn. and the Copper and Brass Research Assn., as well as certain individual manufacturers' publications, have been carefully considered. In general, reference is made to existing standards by number, and such standards are to be considered as much a part of this document as if included in their entirety. Certain tables (or parts thereof) are included in this document for convenient reference.

Section 1—General

Sec. 1.1—Definitions

1.1.1. *Service line* is that line of pipe or tubing connected to the water main and leading to the customer's meter for the purpose of supplying water to the premises.

1.1.2. The term *materials* covers: (1) the metal or other material from which the pipe or tubing is made; (2) "corporation cocks," "curb stops" and other valves or fittings on the line.*

Sec. 1.2—Materials Included

Specifications included in this report cover the following service line materials:

Copper Water Tube	Sec. 2
Brass Pipe	Sec. 3
Cast-Iron Pipe	Sec. 4
Lead Pipe	Sec. 5
Wrought-Iron Pipe	Sec. 6
Steel Pipe	Sec. 7

Section 2—Copper Water Tube

Sec. 2.1—Scope

These specifications cover seamless tubes especially designed for underground water services. Such material is designated as "Type K" in the industry.

Sec. 2.2—Specifications

This material will be supplied in conformance with A S.T.M. Specification B88–47, "Type K" if so designated. The material may also be purchased by designating "Type K" under Federal Specifications WW-T-799.

Sec. 2.3—Dimensions

For reference, dimensions derived from the above A.S.T.M. specifications are listed in Table 1.

Section 3—Brass Pipe

Sec. 3.1—Scope

These specifications cover seamless brass pipe suitable for use in water service lines and plumbing.

Sec. 3.2—Specifications

This material will be supplied by designating pipe which conforms to A.S.T.M. Specification B43–47 for red brass pipe. (Yellow brass pipe is not included because the former A.S.T.M. standard for it has been withdrawn.)

Sec. 3.3—Dimensions

For reference, dimensions derived from the above specifications are listed in Table 2.

Section 4—Cast-Iron Pipe

Sec. 4.1—Scope

4.1.1. Cast-iron pipe to be used for water services, where such material is indicated, is subject to the same service as the adjacent mains and therefore the specifications should be the same. They are the "American Standard Specifications for Cast-Iron Pit-cast Pipe for Water or Other Liquids (A21.2—1939)."

* See A.W.W.A. Standard Specifications for Threads for Underground Service Line Fittings—7T.1—1948.

TABLE 1

Standard Dimensions and Weights, and Tolerances in Diameter and Wall Thickness of Type K Copper Water Tube†*

Standard Water Tube Size *in.*	Actual od. *in.*	Average od. Tolerance *in.*		Wall Thickness *in.*		Theoretical Weight per Foot *lb.*
		Annealed	Drawn	Nominal	Tolerance	
½	0.625	0.0025	0.001	0.049	0.004	0.344
⅝	0.750	0.0025	0.001	0.049	0.004	0.418
¾	0.875	0.003	0.001	0.065	0.0045	0.641
1	1.125	0.0035	0.0015	0.065	0.0045	0.839
1¼	1.375	0.004	0.0015	0.065	0.0045	1.04
1½	1.625	0.0045	0.002	0.072	0.005	1.36
2	2.125	0.005	0.002	0.083	0.007	2.06
2½	2.625	0.005	0.002	0.095	0.007	2.93
3	3.125	0.005	0.002	0.109	0.007	4.00
3½	3.625	0.005	0.002	0.120	0.008	5.12
4	4.125	0.005	0.002	0.134	0.010	6.51
5	5.125	0.005	0.002	0.160	0.010	9.67
6	6.125	0.005	0.002	0.192	0.012	13.9

* Extracted from Table II of "Standard Specifications for Copper Water Tube (B88-47)," *1947 Supplement to Book of A.S.T.M. Standards, Part I-B—Nonferrous Metals.* Am. Soc. for Testing Materials, Philadelphia (1947).

† For tubes other than round no standard tolerances are established. These tolerances do not apply to condenser and heat-exchanger tubes. All tolerances in this table are plus and minus.

TABLE 2

*Standard Dimensions and Weights of Red Brass Pipe**

Pipe Size *in.*	od. *in.*	Regular Pipe		Extra-Strong Pipe	
		Wall Thickness *in.*	Nominal Weight per Foot—*lb.*	Wall Thickness *in.*	Nominal Weight per Foot—*lb.*
½	0.840	0.107	0.934	0.149	1.23
¾	1.050	0.114	1.27	0.157	1.67
1	1.315	0.126	1.78	0.182	2.46
1¼	1.660	0.146	2.63	0.194	3.39
1½	1.900	0.150	3.13	0.203	4.10
2	2.375	0.156	4.12	0.221	5.67
2½	2.875	0.187	5.99	0.280	8.66
3	3.500	0.219	8.56	0.304	11.6
3½	4.000	0.250	11.2	0.321	14.1
4	4.500	0.250	12.7	0.341	16.9
5	5.562	0.250	15.8	0.375	23.2
6	6.625	0.250	19.0	0.437	32.2

* Extracted from Table I of "Standard Specifications for Red Brass Pipe, Standard Pipe Sizes (B43-47)," *1947 Supplement to Book of A.S.T.M. Standards, Part I-B—Nonferrous Metals.* Am. Soc. for Testing Materials, Philadelphia (1947).

4.1.2. No specification is included for pipe cast by the centrifugal process. Until the A.W.W.A. has adopted an A.S.A. standard specification, it is recommended that centrifugally cast pipe be purchased by reference to Federal Specification WW-P-421.

Sec. 4.2—Specifications

Pit-cast cast-iron pipe conforming to A.S.A. Specification A21.2—1939 will be supplied if so designated.

Sec. 4.3—Dimensions

For reference, dimensions derived from the above document are listed in Table 3.

TABLE 3

*Standard Thicknesses and Weights of Cast-Iron Pit-cast Pipe**

Size *in.*	Thickness *in.*	Weight—*lb.*†	
		Per Foot	Per 12-ft. Length‡
3	0.37	14.2	170
4	0.40	19.2	230
6	0.43	30.0	360

* Extracted from Table 3 of the "American Standard Specifications for Cast-Iron Pit-cast Pipe for Water or Other Liquids (A21.2-1939)." Am. Water Works Assn., New York (1939).

† Weights and dimensions apply to pipe of Class 50 (50-psi. pressure, 115-ft. head), Class 100 (100-psi. pressure, 231-ft. head), Class 150 (150-psi. pressure, 346-ft. head) and Class 200 (200-psi. pressure, 462-ft. head). These weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft. of cover; for other conditions see *ibid.*, Table 4.

‡ Length includes bell and spigot bead. Weight of 12-ft. length is calculated to nearest 5 lb.

TABLE 4

*Lead Pipe Sizes**

Nominal id. *in.*	Classification		Maximum Working Pressure *psi.*	od. *in.*	Minimum Outside Circumference—*in.*	Wall Thickness *in.*	Nominal Weight per Foot *lb.*
	East†	West‡					
$\frac{3}{8}$	AA	XS	75	0.811	$2\frac{3}{8}$	0.218	2.00
	AAA	XXS	100	0.888	$2\frac{5}{8}$	0.256	2.50
$\frac{1}{2}$	AA	XS	75	0.876	$2\frac{5}{8}$	0.188	2.00
	AAA	XXS	100	1.012	$3\frac{1}{16}$	0.256	3.00
$\frac{5}{8}$	AA	XS	75	1.082	$3\frac{1}{4}$	0.228	3.00
	AAA	XXS	100	1.137	$3\frac{7}{16}$	0.256	3.50
$\frac{3}{4}$	AA	XS	75	1.212	$3\frac{11}{16}$	0.231	3.50
	AAA	XXS	100	1.336	$4\frac{1}{16}$	0.293	4.75
1	AA	XS	75	1.492	$4\frac{9}{16}$	0.246	4.75
	AAA	XXS	100	1.596	$4\frac{7}{8}$	0.298	6.00
$1\frac{1}{4}$	AA	XS	75	1.765	$5\frac{3}{8}$	0.258	6.00
	AAA	XXS	100	1.889	$5\frac{13}{16}$	0.320	7.75
$1\frac{1}{2}$	AA	XS	75	2.076	$6\frac{3}{8}$	0.288	8.00
	AAA	XXS	100	2.272	7	0.386	11.25
$1\frac{3}{4}$	AA	XS	75	2.404	$7\frac{7}{16}$	0.327	10.50
	AAA	XXS	100	2.624	$8\frac{1}{8}$	0.437	14.75
2	AA	XS	75	2.751	$8\frac{1}{2}$	0.376	13.75
	AAA	XXS	100	3.008	$9\frac{5}{16}$	0.504	19.50

* Extract from Table 1 of "Lead Pipe, Commercial Standard CS95-41." Natl. Bur. of Stds., U.S. Dept. of Commerce, Washington, D.C. (1941).

† Symbols used generally for lead pipe sold in cities east of the Illinois-Indiana line.

‡ Symbols used generally for lead pipe sold in cities west of the Illinois-Indiana line.

TABLE 5

*Standard Weights and Dimensions of Welded Wrought-Iron Pipe**

Nominal id. *in.*	od. *in.*	"Standard Weight" Pipe			"Extra Strong" Pipe		"Double Extra Strong" Pipe	
		No. of Threads per Inch	Thickness *in.*	Weight of Pipe per Linear Foot† *lb.*	Thickness *in.*	Weight of Pipe per Linear Foot‡ *lb.*	Thickness *in.*	Weight of Pipe per Linear Foot‡ *lb.*
½	0.840	14	0.111	0.85	0.151	1.09	0.307	1.71
¾	1.050	14	0.115	1.13	0.157	1.47	0.318	2.44
1	1.315	11½	0.136	1.68	0.183	2.17	0.369	3.66
1¼	1.660	11½	0.143	2.28	0.195	3.00	0.393	5.21
1½	1.900	11½	0.148	2.73	0.204	3.63	0.411	6.41
2	2.375	11½	0.158	3.68	0.223	5.02	0.447	9.03
2½	2.875	8	0.208	5.82	0.282	7.66	0.567	13.70
3	3.500	8	0.221	7.62	0.306	10.25	0.615	18.58
3½	4.000	8	0.231	9.20	0.325	12.51	0.651	22.85
4	4.500	8	0.242	10.89	0.344	14.98	0.690	27.54
5	5.563	8	0.263	14.81	0.383	20.78	0.768	38.55
6	6.625	8	0.286	19.19	0.441	28.57	0.884	53.16

* Extracted from Table II of "Standard Specifications for Welded Wrought-Iron Pipe (A72–45)," *1946 Book of A.S.T.M. Standards, Part I-A—Ferrous Metals.* Am. Soc. for Testing Materials, Philadelphia (1947).
† Threaded and with couplings.
‡ Plain ends.

Section 5—Lead Pipe

Sec. 5.1—Scope

A National Bureau of Standards document, CS95–41, covers chemical analysis, inside and outside diameter, weight per foot, defects, certification and labeling of one grade of lead pipe. A recommended guide to the selection of the proper classification of lead pipe for various purposes and localities is also included. Lead pipe designed for a working pressure below 75 psi. is not recommended as advisable for use in underground service lines.

TABLE 6

*Hydrostatic Test Pressures for Welded Wrought-Iron Pipe**

Nominal id. *in.*	"Standard Weight" Pipe		"Extra Strong" Pipe		"Double Extra Strong" Pipe	
	Butt-welded	Lap-welded	Butt-welded	Lap-welded	Butt-welded	Lap-welded
	psi.					
½ to 1, incl.	700		850		1,000	
1¼ to 3, incl.	800†	1,000	1,100†	1,500	1,200†	1,800
3½ to 6, incl.		1,200		1,700		2,000

* Extracted from Table I of the "Standard Specifications for Welded Wrought-Iron Pipe (A72–45)," *1946 Book of A.S.T.M. Standards, Part I-A—Ferrous Metals.* Am. Soc. for Testing Materials, Philadelphia (1947).
† Butt-welded pipe is not made in nominal sizes larger than 2 in.

TABLE 7

*Standard Weights and Dimensions of Welded and Seamless Steel Pipe**

Nominal id. *in.*	od. *in.*	"Standard Weight" Pipe: No. of Threads per Inch	"Standard Weight" Pipe: Wall Thickness *in.*	"Standard Weight" Pipe: Weight of Pipe per Linear Foot *lb.* — Plain†	"Standard Weight" Pipe: Weight of Pipe per Linear Foot *lb.* — Threaded‡	"Extra Strong" Pipe: Wall Thickness *in.*	"Extra Strong" Pipe: Weight of Pipe per Linear Foot† *lb.*	"Double Extra Strong" Pipe: Wall Thickness *in.*	"Double Extra Strong" Pipe: Weight of Pipe per Linear Foot† *lb.*
½	0.840	14	0.109	0.85	0.85	0.147	1.09	0.294	1.71
¾	1.050	14	0.113	1.13	1.13	0.154	1.47	0.308	2.44
1	1.315	11½	0.133	1.68	1.68	0.179	2.17	0.358	3.66
1¼	1.660	11½	0.140	2.27	2.28	0.191	3.00	0.382	5.21
1½	1.900	11½	0.145	2.72	2.73	0.200	3.63	0.400	6.41
2	2.375	11½	0.154	3.65	3.68	0.218	5.02	0.436	9.03
2½	2.875	8	0.203	5.79	5.82	0.276	7.66	0.552	13.70
3	3.500	8	0.216	7.58	7.62	0.300	10.25	0.600	18.58
3½	4.000	8	0.226	9.11	9.20	0.318	12.51		
4	4.500	8	0.237	10.79	10.89	0.337	14.98	0.674	27.54
5	5.563	8	0.258	14.62	14.81	0.375	20.78	0.750	38.55
6	6.625	8	0.280	18.97	19.18	0.432	28.57	0.864	53.16

* Extracted from Tables I, III and IV of "Standard Specifications for Black and Hot-dipped Zinc-coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A120–47)," *1947 Supplement to Book of A.S.T.M. Standards, Part I-A—Ferrous Metals.* Am. Soc. for Testing Materials, Philadelphia (1948).

† Plain ends.

‡ Threaded, and with couplings.

TABLE 8

*Hydrostatic Test Pressures for Welded and Seamless Steel Pipe**

Nominal id. *in.*	"Standard Weight" Pipe: Butt-welded	"Standard Weight" Pipe: Lap-welded, Electric-welded and Grade A	"Standard Weight" Pipe: Grade B	"Extra Strong" Pipe: Butt-welded	"Extra Strong" Pipe: Lap-welded, Electric-welded and Grade A	"Extra Strong" Pipe: Grade B	"Double Extra Strong" Pipe: Butt-welded	"Double Extra Strong" Pipe: Lap-welded, Electric-welded and Grade A	"Double Extra Strong" Pipe: Grade B
	psi.								
⅛ to 1, incl.	700	700†‡	700‡	850	850†‡	850‡	1,000	1,000†‡	1,000‡
1¼ to 3, incl.	800	1,000	1,100	1,100	1,500	1,600	1,200	1,800	1,900
3½ to 6, incl.	1,200§	1,200	1,300	1,700§	1,700	1,800		2,000	2,100

* Extracted from Tables I, III and IV of "Standard Specifications for Black and Hot-dipped Zinc-coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A120–47)," *1947 Supplement to Book of A.S.T.M. Standards, Part I-A—Ferrous Metals.* Am. Soc. for Testing Materials, Philadelphia (1947).

† Lap-welded pipe is not made below 1¼-in. size.

‡ Seamless pipe in these small sizes will probably need to be cold drawn.

§ Butt-welded pipe is not made in sizes larger than 4 in. nominal.

Sec. 5.2—Specifications

Material suitable for water service lines will be supplied in conformance with National Bureau of Standards Document CS95–41 if so designated.

Sec. 5.3—Dimensions

For convenient reference, dimensions derived from the above document are given in Table 4 for Class 75 and Class 100 pipe.

Section 6—Wrought-Iron Pipe

Sec. 6.1—Scope

These specifications cover the furnishing of wrought-iron pipe, either plain or galvanized, for use in underground water service lines.

Sec. 6.2—Specifications

This material will be supplied in conformance with A.S.T.M. Specification A72–45 or Federal Specification WW–P–441a if so designated. A special note must be added to indicate whether black or galvanized pipe is desired. If the A.S.T.M. specification is used, galvanizing should be specified to be in accordance with A.S.T.M. Specification A90–39. If cement-lined pipe is desired, it must be specially noted that the lining shall conform to Federal Specification WW–P–406.

Sec. 6.3—Dimensions

For convenient reference, dimensions derived from the above A.S.T.M. specifications are given in Table 5.

Sec. 6.4—Hydrostatic Pressures

For reference, hydrostatic test pressures derived from the above specifications are listed in Table 6.

Section 7—Steel Pipe

Sec. 7.1—Scope

These specifications cover the furnishing of steel pipe, either plain or galvanized, for use in underground water service lines.

Sec. 7.2—Specifications

This material will be supplied in conformance with A.S.T.M. Specification A120–47, or Federal Specification WW–P–406, Type I, if so designated. Whether black or galvanized pipe is desired must be specially noted. If cement-lined pipe is desired, it must be specially noted that the lining shall conform to Federal Specification WW–P–406.

Sec. 7.3—Dimensions

For reference, dimensions derived from the above A.S.T.M. specifications are listed in Table 7.

Sec. 7.4—Hydrostatic Pressures

For reference, hydrostatic test pressures derived from the above A.S.T.M. specifications are given in Table 8.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *B.H.—Bulletin of Hygiene* (*British*); *C.A.—Chemical Abstracts; Corr.—Corrosion; I.M.—Institute of Metals* (*British*); *P.H.E.A.—Public Health Engineering Abstracts; S.W.J.—Sewage Works Journal; W.P.R.—Water Pollution Research* (*British*).

DISTRIBUTION SYSTEMS, METERS AND SERVICES

Studies of the Consumption and Wastage of Water in Distribution Systems and Current Causes of Waste. ROLAND B. QUENEAU. J. Inter-American Assn. San. Eng. **1**:181 (Oct. '47). Pitometer studies useful for detecting water waste and for planning distr. system improvements in orderly, efficient and economical manner. Location and repair of leaks in distr. system and in domestic and industrial installations conserves water, reduces treatment and distr. costs, postpones need for addnl. pumping, elims. or postpones need for new feeders, elims. possibility of damage due to undermined pavements or bldgs., increases water pressure, and reduces water flow in sewerage systems. Location of areas with excessive demand facilitates waste reduction through metering. Discovery of unauthorized connections and of meters in need of repair increases water revenues. Finding cross-connections protects public health. Inspection of valves in system during survey improves operation. Pump eff. tests indicate means of lowering pumping costs. Principal causes of subsoil leakage are: Pipe deterioration through corrosion and electrolysis, defective materials, poorly installed pipes, earth tremors and water hammer. Pitometer survey procedure, and equip. and methods of locating leaks described. Data on water consumption and examples of water waste problems solved with aid of pitometer surveys in U.S., Canada and South and Central American cities presented.—*J. M. Sanchis.*

Nozzles, Valves and Flushing Apparatus. STEINWENDER. Gas, Wasser, Wärme (Ger.) **1**:241 (Oct. '47). Description of various types of apparatus. Careful regulation of water consumption necessary, because in bombed cities leaks in pipes difficult to find; because of neglect, domestic water consumption 50–100% higher than before war; vegetable gardens require 25% of total water; waste caused by running of taps during winter to prevent freezing in poorly heated houses. Requests, orders, newspaper notices and handbills had so little effect that water distr. stopped for some hours during day. Lowering of pressure resorted to. Regulation of nozzles, valves and flush toilets saved Vienna daily 20,000 cu.m. of water. Several different types of valves installed; all piping to flush toilets reduced to ½".—*W. Rudolfs.*

Check Valves, Traffic Cops of the Pipelines. H. J. BARTLETT. The Ladle **24**:1:8, **24**:2:22 (Jan. '48). Describes various types of swing and lift check valves and their applications.—*Ed.*

Uses of Controlled Globe Type Valves. ANGUS D. HENDERSON. W.W. Eng. **100**:1209 (1947). Use of globe-type valves as check valves and backflow preventers, as pressure-relief valves and for level control of elevated tanks, standpipes and reservoirs, described.—*Ed.*

Los Angeles Program Speeds Reconditioning of Cast-Iron Pipe. R. E. HEMBORG. Eng. News-Rec. **140**:46 (Jan. 8, '48). Cast-iron pipe, removed from water service because of revisions of street grades or necessity for larger lines, is reconditioned for re-use in Los Angeles system by relatively simple process. Pipe is hand scraped, grit blasted, mortar lined and coated with coal-tar enamel.—*Ed.*

Important Fundamentals for the Repair of Distribution Systems. Ernst Daur. Gas- u. Wasser. (Ger.) **88**:6:173 ('47). In Pforzheim, Wurtemberg, center of city and 80 per cent of residential area completely destroyed. Water plant suffered relatively little. Repair of distribution system showed that underground river crossings not damaged, but those on bridges were. Valves concentrated in manholes easier to find and handle than single valves under valve boxes. Even if prints of general plans of system available, lack of detailed local plans can hinder work. Important local plans should be kept in fireproof safes. Besides detailed maps showing location of mains and valves, inventory listing of all valves, giving age, very useful.—*Max Suter.*

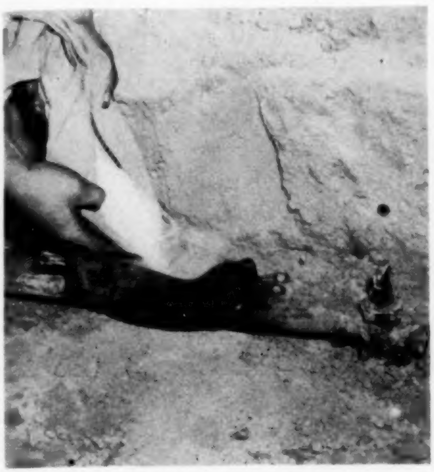

Fig. 1. Rubber Freezing Pocket

Quick Freezing of Service Pipes Speeds Repair Work. John L. Ford. W. W. Eng. **100**:1365 (Nov. 12, '47). In replacing curb valve or lengthening service to it, shutting off pressure is great advantage. Shutting off corporation stop on main usually impractical because of expense or amount of digging involved. Rubber plug on rod sometimes is pushed through open curb valve and expanded to stop flow, but valves with narrow water passage will not pass plugs large enough. Rubber plug useless when service pipe is being lengthened, as plug cannot be removed after work completed. In some water works it has been common practice for years to freeze water in pipes to serve as plug. During freezing process flow must be stopped or rate reduced to permit freezing. Principal advantage of using dry ice (solid CO_2) for pipe freezing is that it is so cold it works amazingly fast. Also it is clean to handle and is easily obtainable from frozen vegetable distributors or ice cream shippers. Following procedure is simple and quick: piece of old inner tube, 8′ × 10″, is centered under pipe and brought up and fastened together with wide, strong clamps; rubber should be left loose from end to end to form pocket (*see* Fig. 1 and 2). For freezing 65°F. water in $\frac{3}{4}$-in. steel pipe, 1 lb. of powdered dry ice is poured into pocket and $\frac{1}{4}$ pint of alcohol added. Antifreeze, gasoline or naphtha can be used, though latter two are hard on rubber. If flow entirely stopped, or up to 0.033 gpm., water freezes solid in 2–5 min. When no alcohol or other liquid is added, it takes several times as long to freeze pipe with dry ice. To test whether pipe is frozen: if valve drips, this can be watched to note when flow stops, indicating pipe is frozen; if valve does not drip, 5 min. should be

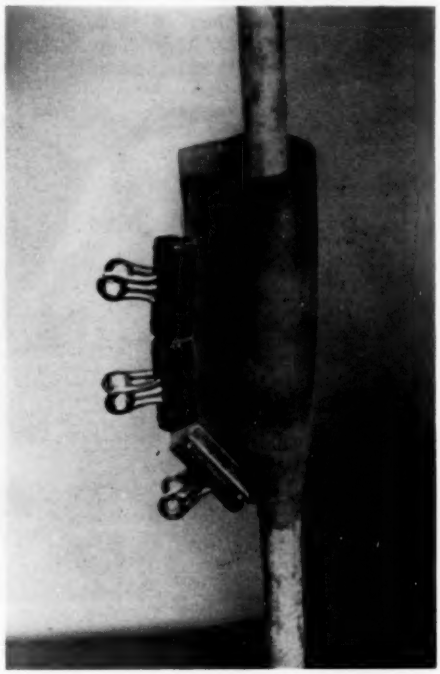

Fig. 2. Pocket for Vertical Pipe

allowed after dry ice and liquid have been applied, and valve opened cautiously. Even if pipe frozen, small amount of water under pressure between ice plug and valve will be noted when valve opened; if flow continues, however, valve should be closed and another 5 min. allowed. Once frozen, pipe will remain so as long as rubber pocket contains dry ice, which may be added if necessary. To thaw pipe, rubber is removed and warm water or torch applied. Rubber can be re-used, and expense of method is only 15¢ for material. Pipe will suffer no damage. Method cannot be used if flow greater than approximately 0.067 gpm. CO_2 given off is not poisonous but can cause suffocation if breathed in great concentration; however, small quantities used in pipe freezing make danger negligible. Little fire hazard from alcohol or gasoline because of low temperatures.—*Ed.*

The Freez-Seal Method. ANON. Pamphlet released by Freez-Seal Equipment Co., Ltd., New Malden, Surrey, England (1946). Freez-Seal equipment (patents applied for) is designed to form ice plug in pipe to be repaired; ice plug is formed in special way "under conditions which eliminate all possibility of damage to pipe which might otherwise be caused by expansion of ice plug." Two types of equipment: (1) portable mechanical refrigerator and (2) nonmechanical unit. Mechanical unit (Fig. 3), weighing 70 lb., consists of small standard refrigerator type of compressor with condenser and fan, all coupled to prime mover (gasoline engine or electric motor) absorbing $\frac{1}{6}$ hp. Hinged clip (Fig. 4) forms expansion chamber for refrigeration circuit and is fixed in position on pipe close to defective portion to be repaired. After flow of water in pipe has been stopped, except for slight drip at controlled rate, section of pipe within clip is frozen. "Closing tool" or special sealing clamp used to stop flow from damaged portion of pipe before clip (expansion chamber) is attached. Drip cock (Fig. 5) fitted to sealing clamp permits small leakage to escape from pipe, which indicates when water is frozen and relieves pressure within pipe during formation of ice plug. Ice plug forms gradually and freezing process does not give rise to bursting tendency, but takes place throughout at same pressure as that of water in main. Refrigerant is contained in closed circuit and suffers no deterioration or loss. Nonmechanical unit consists of hinged container which is fixed to pipe to be repaired. Container is then charged with suitable refrigerant such as CO_2

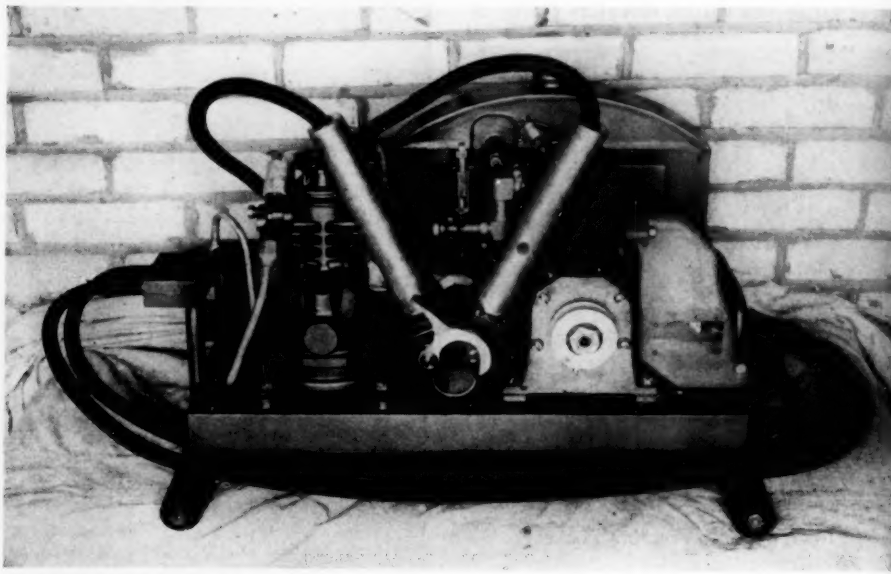

FIG. 3. Portable Freezing Unit

or CO_2-methyl alcohol mixture. If CO_2 is used, means are provided to relieve pressure of gas given off. Container very similar to mechanical unit, same methods used for temporary sealing of flow and for providing controlled drip. Both units designed to fit pipes in any position and will accomodate lead, steel and copper pipes of different standard od. Laboratory and field tests have shown that freez-seal process can be applied to water service pipes no matter how deteriorated without affecting pipe strength. Time taken to freeze pipes depends on pipe material, air and water temperature and other factors. From experience, ½-in. pipe requires 3–6 min.; ¾-in. pipe, 6–9 min.; and 1-in. pipe, 9–15 min. Advantages claimed for freez-seal method include:

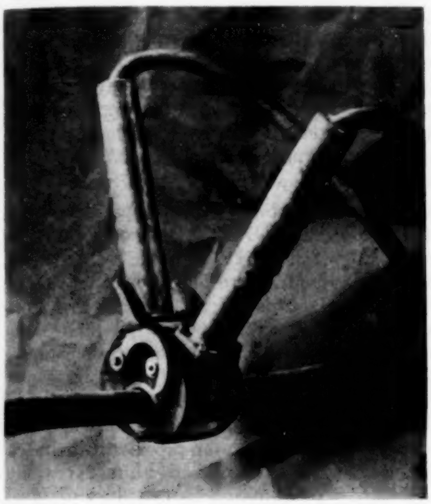

FIG. 4. Hinged Clip

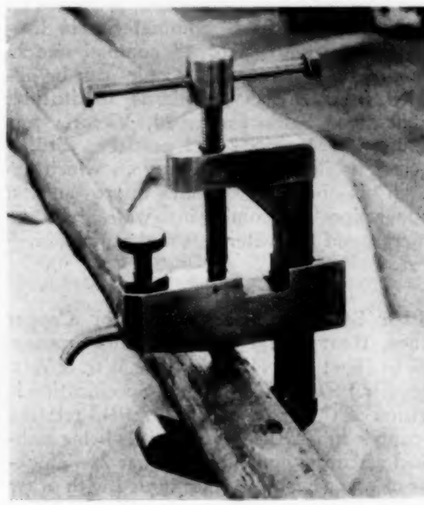

FIG. 5. Clamp and Drip Cock

(1) no possibility of contamination of water supply due to pressure reduction or emptying of main; (2) less inconvenience to consumers and operators; (3) perfect seal free of drips; (4) no cloudy or discolored water resulting; (5) less chance of air locks or damage to fittings; (6) less waste of water; (7) saving of labor, time and expense.—*Ed.*

Use of Copper Pipes in Large Water Supply Schemes. A. CLOUSTON. New Zealand Eng. p. 1260 (Dec. 10, '47). Water mains situated under wharves have to endure extremely severe corrosion conditions owing to proximity of salt water and varying temp. Such mains also have to convey large quants. of water for fire fighting and to supply vessels. At Wellington Harbor 4-in. water main of galvanized steel pipe suspended under wharf by mild steel hangers, but life of this main only about 12–15 yr. During '45 Harbor Board faced with problem of replacing this main and possibility of using copper main in place of galvanized steel considered. Ests. showed cost of compression joints would be high and it was decided to investigate possibility of using low temp. brazing as medium for all joints. Expts. and further ests. showed that higher cost of using copper pipe would be offset by considerable saving in labor costs, as much of work could be carried out in workshop, whereas with iron pipe it would be necessary to execute whole of work out on job, necessitating use of punts and difficult work over concrete beams of wharf. Some 1872′ of 4″ by 13-gage H.H. copper pipe and 448′ of 2½″ by 16-gage H.H. copper pipe for fire plug connections ordered and 6 lb. of ⅛″ Silfos and 2 lb. of ⅛″ Easyflo specially ordered from England. Although 2½″ diam. copper pipe used to replace existing 3″ diam. main, as anticipated, due to much less frictional loss in pipes, delivery increased from 217 to 288 gpm. Method of joining 16′ lengths of 4″ pipe was by expanding ends of copper pipe with steel mandrel; this joint made with Silfos using No. 4 tip in workshop

and No. 6 tip on job. Work underneath wharf done wholly by gang of 3 men, pipes being suspended on hardwood blocks to stop any possibility of copper coming into contact with iron rods. Working pressure of these mains between 100 and 140 psi. Another hydraulic main working under pressure of 750 psi. replaced by $\frac{3}{4}''$ diam. by 10-gage H.H. copper pipe. After two years' operation these pipelines entirely satisfactory.—*Ed.*

British Standard for Copper Tubes to be Buried Underground. B.S. 1386:1947. ANON. Wtr. & Wtr. Eng. (Br.) **50**:511 (Oct. '47). Standard covers solid-drawn copper tubes which are to buried underground for conveyance of water, gas, etc. Specification covers copper tubes for working pressures up to 200 psi., $\frac{3}{8}''$ to $1\frac{1}{4}''$ nominal size in long length coils, and $\frac{1}{8}''$ to $4''$ nominal size in straight random lengths. Copies can be obtained from British Standards Institution, Publications Sales Dept., 24, Victoria St., London S.W. 1; price 2s net, postfree. Std. of interest as illustration of way in which research is bringing about improvements. Copper pipes now coming into widespread use underground for water, gas and sanitation.—*H. E. Babbitt.*

British Standard Specification for Copper Tubes, Heavy Gage, for General Purposes. B.S. 61 (Part 1); 1947. ANON. Wtr. & Wtr. Eng. (Br.) **50**:512 (Oct. '47). Specification is revision of that part of B.S. 61:1913 relating to copper tubes, threading details being published separately as B.S. 61, Part 2. Thickness of tubes has been coordinated with other specifications in order to simplify range of copper tubes recognized as std. Number of slight alterations have been made in od. of tubes and clauses have been added covering tests. Copies can be obtained from British Standards Institution, Publications Sales Dept., 24, Victoria St., London S.W. 1.; price 2s, postfree.—*H. E. Babbitt.*

Protection of Water Supply: Headworks to Consumer. A. D. MEAD. Originally published in New Zealand Engineering, March '47. Wtr. & Wtr. Eng. (Br.) **50**:401 (Aug. '47). First concern effective sterilization of trunk water main. Dose generally recommended of order of 10 ppm. Best protection of service reservoirs is by roof monolithic with walls. Rules for sterilization of network of feeder and reticulation mains similar to those for trunk mains. Faults on consumers' premises offer most usual risk to purity of supply after leaving filters. Conditions of complete safeguarding are: (1) service pipes always full and under pressure, (2) they should have no phys. connection with other liq.-contg. pipes or vessels; and (3) taps from which water drawn should be in open, above fitting or container which will receive water. It cannot be too strongly insisted that 2 systems (pold. and unpold. water) must be kept distinct. Proffered safeguards, such as nonreturn valves, not sufficiently reliable. Piping direct to taps usually regarded as ideal from hygienic standpoint. For certain types of occupation uninterrupted supply so vital that reserve storage on premises becomes necessary. Hygienic care of cistern necessary. It must have close-fitting but not air-tight lid, placed where not too difficult of access, and not liable to contamn. Well-drawn set of by-laws, capable inspectors, reading of journals, and executive determination are all links in chain of safeguarding of pure water.—*H. E. Babbitt.*

American Plumbing. A Comparison With British Practice. F. L. BARROW. Wtr. & Wtr. Eng. (Br.) **51**:62 (Feb. '48). (From paper delivered before Royal Sanitary Inst.) *Water supplies:* American supplies are more abundant enabling them to supply 80 or more gpd. (Imp.) per head for domestic consumption, while in Britain 30 gpd. (Imp.) considered good allowance. *Climatic*: In more northerly parts winter temperatures necessitate fixing all soil, waste and rainwater pipes within bldgs. Americans have dispensed almost entirely with cold water storage cisterns in individual houses. One effect of this practice is that hot water storage tanks are at main pressure. Such tanks have no expansion pipes, such as British use. Advantage of taking supplies from mains is simplicity of pipe work, saving of cistern room, and elimination of risk of freezing at cistern or of pollution introduced at water surface. Flushing water quantities for American closets may be double usual British 2 or 3 gal. American requirements as regards soil pipe sizing and antisiphonage ventilation are not same as British. In more expensive private dwellings one would be likely to find flushing valves but in housing generally it is normal to use flushing cistern, as British do. It is only within last 20 yr. or so that it has become recognized in America that when

water is served to appliance without interposing cistern open to atmospheric pressure, any "submerged inlet" on appliance can produce serious risk of back-siphonage. There is no way with conventional closet pans of avoiding submerged inlet. American remedy now being applied in case of unavoidable submerged inlet is backflow preventer. In British practice flushing valves are not supplied directly from mains. British permit submerged inlets by not lifting tap outlet above flood rim as Americans do. In U.S. and Canada one-pipe internal stack system is practically universal. British would not give unqualified approval to internal stacks, but accept them only when dangers of leakage, particularly over food, have been fully considered. Economy in pipe work, junctions and manholes which may be obtained by using one-pipe plumbing is fairly obvious. One of effects of summer climate in North America is prevalence of showers for bathing. Where possible shower is used as auxiliary to bath tub. This explains why American bath tubs are 1–2 in. wider and also good deal lower than British. Americans have natural fondness for mechanical devices and new gadget attracts, while British tend to regard novelty with suspicion. This may be one reason Americans developed so many labor-saving devices. Good plumbing and plenty of it is highly regarded by Americans and there is less shyness in talking about it. They seem to be more conscious than British of dangers of infection. For example, they make it much easier to wash after using toilet. Americans appear to use lead, copper, iron, steel and asbestos-cement pipes for much same purposes as British. Their experience with prefabricated plumbing has been closely parallel to British.—*H. E. Babbitt.*

Plumbing Designs for Postwar Buildings. ANON. Wtr. & Wtr. Eng. (Br.) **50**:202 (Apr. '47). Report of Plumbing Committee of Bldg. Research Board notes some common defects in prewar plumbing. Attempt to produce single plumbing design for all districts would be futile. Excessive lengths of pipework in layouts arise when general planning of building has proceeded without due reference to plumbing. Protection against frost dealt with. Pipes should not run near ventilator and should be placed in sheltered locations. Flow test in fully assembled pipe should be made before going beyond prototype stage to assure adequate flow from taps. Among other points mentioned in report are: precautions in case of calked joints within building, traps liable to siphonage, and capac. of cold water storage cisterns. New British standards for baths, wash basins, water-closet suites, hot water tanks, cold water storage cisterns, etc. have been provided.—*H. E. Babbitt.*

Load Equalization in Distribution Systems. H. SCHELLENBERG. Schweiz. Bauzeit. (Swiss) **65**:36:495 (Sept. 6, '47) & Monatsbulletin (Swiss) **27**:11:252 (Nov. '47). While highest load possible on system is theoretically sum of all individual loads, it is well known that this highest load is not reached in distr. system. The probability P that out of n consumers r use their individual max. load for fractional time p per day given by formula:

$$P = \frac{m^r e^{-m}}{r!}$$

where $m = np$. If individual load W_0, momentary load rW_0. Peak that happens most often is that for max. of value of P which corresponds to value r' and is $r'W_0$. Formula shows that in this case $m = W'/W_0$. This is not maximum peak on plant, however, which happens only with probability P'' and corresponding r'' and is $W_{max} = r''W_0$. Value of P'' has to be detd. from experience or from time certain load should not be exceeded. Using various values of m and P'', curves have been drawn which show that r'' increases with increase of m. Value of m can also be calcd. from time, t_0, a consumer uses connection, total time, T, for which the calcn. made, and number, P, of persons per consumer, by formula $m = \frac{nPt_0}{T}$, or (considering total load capac. $W = nW_0$) from $m = WPt_0/W_0T$. Some variables appearing can be considered in practice as constants. Graphs given show numerical relations in metric system and under conditions existing in Europe. Calcn. complicated and recommended only for large projects of distr. but can fundamentally be used not only for water distr. nets, but also for those of gas, steam, electricity and even for traffic loads.—*Max Suter.*

Service Cutoffs in One-Foot Square Holes. FREDERICK BELL. Surveyor (Br.) **106**:635 (Dec. 5, '47). It is std. practice of number of American gas companies to cut off and lay

services with min. excavation at main and in most cases this has been reduced to hole only 1 sq. ft. in area. Liverpool service squads now carry out service cutoffs with no more road excavation than this. Some advantages: (1) reinstatement of opening less expensive than of larger opening; (2) backfilling done so effectively that surface ready for immediate reinstatement; (3) less heavy digging required; (4) use of special tools and different technique has provided opportunity for workmen to show initiative and skill in handling equip.; (5) work can be done more rapidly and labor cost smaller. Normal cutoff from start to finish takes hour or so, even through concrete road.—*H. E. Babbitt.*

The Design of Metered Connections. ANON. Wtr. & Wtr. Eng. (Br.) **50**:528 (Nov. '47). Factors governing size of metered connection are: (1) rate at which water required, (2) height at which water is to be delivered, (3) pressure in main from which supply afforded and (4) total loss of head from main to delivery. Connection should be designed to give max. required rate of flow. If storage tank with capac. sufficient to balance demand over 24 hr. is installed, design capac. of connection will be hourly rate given by total daily demand divided by 24. More usual set of conditions is, for example, quant. of 8000 gpd., in 2 peak periods of 2 hr. each, with storage tank of 1000 gal. capac. Rate of discharge at connection would be $(8000 - 1000) \div 6 = 1.160$ gph. Height required is highest part of supply pipe through which water is discharged into storage tank above main from which connection is to be made. Engr. must be careful to use pressure in main which obtains when consumers' peak demand likely to occur. Computation of loss of head from main to storage tank involves knowledge of size of connection and must be made by trial.—*H. E. Babbitt.*

London (Ont.) Program of Water Meter Testing Yields Good Results. T. HODKINSON. Eng. Cont. Rec. (Can.) **60**:5:102 (May '47). Meters tested according to following schedule: 1″ and smaller every 5 yr., 1½″–2″ every 3 yr., 3″–8″ every 2 yr. Adoption of this program increased revenue and reduced unaccounted-for water. Results of tests of domestic meters given which indicate loss of sensitivity during 5-yr. service. All meters should be tested immediately before being placed.—*R. E. Thompson.*

Develop Method of Drilling for Water Connections at Woodstock (Ont.). J. R. SULLIVAN. Eng. Cont. Rec. **60**:4:84 (Apr. '47). Extensions in '46 to meet increasing demand included 3 wells, 16″ diam., in spring area 4 mi. from city; 6799′ mains and 100 services. Latter installed by opening trench at main and at curb box, using air drill to bore from one to other, and drawing copper tubing back through hole as boring pipe withdrawn. Necessary equip. transported in trailer attached to compressor.—*R. E. Thompson.*

Designing Indoor Water Services. L. B. ESCRITT. Surveyor (Br.) **105**:149 (Feb. 22, '46). In detg. sizes of water mains, usual to allow for peak flow of 3 times avg. rate during 24 hr. and to select size of pipe that will give economic velocity, frequently around 2.75 fps. When service lines inside large buildings are to be designed, conditions different. Peak flow rates greatly exceed avg. demand. Allowance must be made for number of fittings probably to be used at once. Tables and curves have been made up recommending factors by which simultaneous demand of any number of fittings can be crudely estimated. Most economic scheme indoors is that in which hydraulic gradient more or less constant throughout system.—*H. E. Babbitt.*

Economic Considerations on the Water Supplies of Cities and Settlements. ERWIN NEUMANN. Gas u. Wasser. (Ger.) **88**:3:69 ('47). Need for cheaper and better living quarters suggested use of cheap farm lands for settlements. These require large initial cost to make them accessible. Cost of utilities and amt. of materials needed increase greatly per resident as houses spread farther apart. These facts should be given more consideration by city planners. Data given for German conditions, showing that single-house settlements need 14 to 22 times as much material per resident as multiple story bldgs. Pressure loss in distr. systems and peak loads also greater in settlements, especially where gardens sprinkled. Often need for fire protection governs pipe sizes. Single wells for each house not recommended as treatment cannot be maintd. and sanitary conditions not satisfactory if central sewer system lacking.—*Max Suter.*

Simplified Sewer and Water Main Calculations for Housing Schemes. C. C. JUDSON. Surveyor (Br.) **106**:345 (July 4, '47). Author

describes extensive work required in calculation of estimates for sanitary sewers, storm sewers and water mains needed for proposed housing developments. To aid other engineers in preparation of these estimates author has included tables covering essential items for: (1) foul sewers on housing sites; (2) water mains on housing sites; and (3) design of small surface-water sewers on housing sites.—*P.H.E.A.*

TUNNELS AND AQUEDUCTS

Second Aqueduct for East Bay. ANON. Western Constr. News. **22**: 8: 75 (Aug. '47). Duplication of 94-mi. Mokelumne R. Aqueduct of East Bay Munic. Utility Dist. serving water to east shore cities of San Francisco Bay made necessary by wartime growth of area. Present system completed in '29 to deliver 50 mgd. by gravity. Designers anticipated need for more capac. by purchasing 100′ right-of-way and constructing outlet works, tunnels, etc., in duplicate. Pumping plants built along line increased flow to 95 mgd. With new aqueduct and 4 pumping plants, delivery to be 200 mgd. Avg. demand in '46 was 104 mgd., supplied by aqueduct and local watersheds. New aqueduct to cost $22,000,000. Interesting description of constr. materials, methods and problems.—*A. C. Rener.*

Water Supply Job Follows 1924 Plans. ANON. Eng. News-Rec. **140**: 50 (Jan. 8, '48). Construction of Second Mokelumne Aqueduct in California follows closely plan of water supply development laid down more than two decades ago. Construction on pipeline similar in general nature to that done on original line completed in 1929, but improvements in field-welding techniques and in steel-pipe coating and lining procedures assure better job at this time. New aqueduct will bring approximately 200 mgd. of water from Sierra Nevada to East Bay Municipal Utility District.—*Ed.*

Phenomenal Colonization of Diatoms in Aqueducts. A. D. HARDY. Proc Roy. Soc. Victoria (Australia) **55**: II: 229 ('43). Cause of algal infestation of Melbourne water works which has occurred seasonally since '41 in hitherto unaffected 12-yr-old aqueduct has not been detd. satisfactorily but suggested that much C and ash entered highland streams during forest fires of '39 and, with silica resulting from subsequent erosion, afforded abundance of diatom shell-building material.—*C.A.*

New 72-in. Pipeline to By-pass Soft Bottom of San Francisco Bay. N. A. ECKART. Eng. News-Rec. **139**: 49 (Jul. 10, '47). To increase capacity of Hetch Hetchy Aqueduct, 47 mi. of 62-in. pipe will be laid across San Joaquin Valley, and third San Francisco Bay pipeline will be laid on dry land, away from other two, for safety.—*Ed.*

Water Pipeline on the Desert Floor. ANON. Eng. News-Rec. **138**: 889 (May 29, '47). Constr. of 223-mi. pipeline, 30″–21″ id., in South Australia.—*Ed.*

Submarine Pipelines in Deep Water at Portland, Maine. JAMES R. GARDNER. J.N.E. W.W.A. **59**: 148 (June '45). War demands necessitated connections from Portland Water Dist. to several islands in Portland Harbor. Lack of c-i. pipe, severe winter, harbor regulations, and shortage of labor overcome by use of wrought-iron pipe, welded into 200′ sections, and many ingenious expedients. In deeper waters longer sections laid by "controlled buoyancy" using mine net floats. Another line had to be laid in trench 25′ below bottom of water to allow for future dredging. 250′ U-shaped sections built on shore floated into place and connected by flexible c-i. ball joints. When c-i. pipe became available later, sections of 8″ and 12″ laid under 120′ of water, which is believed to be record depth for 60′ sections lowered by strongback and bolted together below surface by divers. One serious break which occurred located by divers. Repair section built by means of templates made in deep water, lowered in place and connected successfully.—*P.H.E.A.*

Transite Pipes in Tunnel Form New Feeder Main for St. Catharines. W. G. MCLAUGHLIN. Wtr. & Sew. (Can.) **85**: 2: 13 (Feb. '47). In 1878, dam built across Beaver Dams Creek just upstream from Decew Falls, creating 65-acre storage reservoir, el. 160′ above city, maintg. 65–70 psi. pressure in distr. system. As demand increased and runoff decreased, water diverted from Welland Ship Canal into reservoir, and practically whole supply now so obtained. Original 16″ c-i. feeder main to city has capac. of 2.5 mgd. In '13, second feeder main installed, consisting of 4000′ un-

lined tunnel through limestone from reservoir to face of escarpment and 24″ c-i. main 15,000′ from this point to city. In '26, 10-mgd. filter plant and 5-mil.gal. filtered water reservoir placed in commission, latter discharging into tunnel. Tunnel passes under forebay (Gibson Lake) and headrace of power plant, and to elim. possible contamn. from leakage, two 24″ Class 50 asbestos-cement pipelines installed in tunnel in 1946, one connecting with existing 24″ c-i. feeder and other with new one being constructed of 24″ c-i. pipe used as temporary feeder while tunnel out of commission. Laying of asbestos-cement pipe described in some detail, including man-hr. costs. Work involved removal of clay and silt accumulated prior to constr. of filters, straightening and enlarging tunnel to min. section of 6 × 6′, placing concrete floor slab, and laying pipe on precast cradles. Pipe joints consisted of collar and rubber gaskets jacked over machined ends of pipe, those to c-i. pipe being poured with Hydrotite. Only 2 of 602 found defective. When new c-i. pipeline to city completed, feeder lines will have total capac. of 18.5 mgd. Consumption varies from 3 to 8 mgd., and avgs. 6.—*R. E. Thompson.*

Tunnel Lining—Unique Equipment on San Diego Bore. Anon. Western Constr. News **23**: 1: 65 (Jan. '48). San Diego has completed aqueduct from Colorado River and water pouring into San Vicente Res. 20 mi. from city. Contracts awarded for transmission main to city distribution system. Three sections are 68″ reinforced concrete pipe. 4th section is 6′ diameter tunnel 6292′ long being built by L. E. Dixon Co. of Los Angeles. Conventional tunneling methods used averaging 29′ per day. Troublesome water encountered in conglomerate requiring continuous pumping. Novel carloading method used back of mucker by discharging material onto conveyor belt operating over muck cars. This eliminated switching system for advancing empty cars to mucker. Subcontract for concrete lining held by M. F. Kemper Construction Co. of Los Angeles. Tunnel lined to finish surface of 6′ circular diameter. Average thickness from inside surface to rock 17″. Greatest interest in special equipment designed by Kemper firm. Collapsible form 20′ long used with hinged sections. Description of process with series of pictures.—*A. C. Rener.*

Water Pollution Control Act

The signing of the Water Pollution Control Act (Public Law 845, 80 Cong. 2) by President Truman on June 30, 1948, sets a milestone along the road to the recovery of our great natural resource—water. As drawn up, the act is primarily intended to promote research and provide technical guidance and financial aid in planning and constructing waste treatment works. Both surface and ground waters come within the purview of the act.

Federal Security Administrator Ewing, in commenting upon the law, said (in part): "All water uses of each stream will be considered and the [waste] treatment recommended will be based upon these uses."

Administrative responsibility for enforcing the act at federal level is shared by the Federal Security Agency (through the U.S. Public Health Service) and the Federal Works Agency.

No appropriations have as yet been made to provide grants for planning or building waste treatment works.

Following is the text of the Water Pollution Control Act, entitled "An Act to provide for water pollution control activities in the Public Health Service of the Federal Security Agency and in the Federal Works Agency, and for other purposes."

BE IT ENACTED BY THE SENATE AND HOUSE OF REPRESENTATIVES OF THE UNITED STATES OF AMERICA IN CONGRESS ASSEMBLED, That in connection with the exercise of jurisdiction over the waterways of the Nation and in consequence of the benefits resulting to the public health and welfare by the abatement of stream pollution, it is hereby declared to be the policy of Congress to recognize, preserve and protect the primary responsibilities and rights of the States in controlling water pollution; to support and aid technical research to devise and perfect methods of treatment of industrial wastes which are not susceptible to known effective methods of treatment; and to provide Federal technical services to State and interstate agencies and to industries, and financial aid to State and interstate agencies and to municipalities, in the formulation and execution of their stream pollution abatement programs. To this end, the Surgeon General of the Public Health Service (under the supervision and direction of the Federal Security Administrator) and the Federal Works Administrator shall have the responsibilities and authority relating to water pollution control vested in them respectively by this Act.

Sec. 2. (*a*) The Surgeon General shall, after careful investigation, and in cooperation with other Federal agencies, with State water pollution agencies and interstate agencies, and with the municipalities and industries involved, prepare or adopt comprehensive programs for eliminating or re-

ducing the pollution of interstate waters and tributaries thereof hereinafter declared to be a public nuisance and improving the sanitary condition of such interstate waters and tributaries thereof. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life, recreational purposes, and agricultural, industrial and other legitimate uses. For the purpose of this subsection the Surgeon General is authorized to make joint investigations with any such agencies of the condition of any waters in any State or States, and of the discharges of any sewage, industrial wastes, or substance which may deleteriously affect such waters.

(*b*) The Surgeon General shall encourage cooperative activities by the States for the prevention and abatement of water pollution; encourage the enactment of uniform State laws relating to water pollution; encourage compacts between States for the prevention and abatement of water pollution; collect and disseminate information relating to water pollution and the prevention and abatement thereof; support and aid technical research to devise and perfect methods of treatment of industrial wastes which are not susceptible to known effective methods of treatment; make available to State and interstate agencies, municipalities, industries and individuals the results of surveys, studies, investigations, research and experiments relating to water pollution and the prevention and abatement thereof conducted by the Surgeon General and by authorized cooperating agencies; and furnish such assistance to State agencies as may be authorized by law.

(*c*) The consent of the Congress is hereby given to two or more States to negotiate and enter into agreements or compacts, not in conflict with any law or treaty of the United States, for (1) cooperative effort and mutual assistance for the prevention and abatement of water pollution and the enforcement of their respective laws relating thereto, and (2) the establishment of such agencies, joint or otherwise, as they may deem desirable for making effective such agreements and compacts. No such agreement or compact shall be binding or obligatory upon any State a party thereto unless and until it has been approved by the Congress.

(*d*) (1) The pollution of interstate waters in or adjacent to any State or States (whether the matter causing or contributing to such pollution is discharged directly into such waters or reaches such waters after discharge into a tributary of such waters), which endangers the health or welfare of persons in a State other than that in which the discharge originates, is hereby declared to be a public nuisance and subject to abatement as herein provided.

(2) Whenever the Surgeon General, on the basis of reports, surveys, and studies, finds that any pollution declared to be a public nuisance by paragraph (1) of this subsection is occurring, he shall give formal notification thereof to the person or persons discharging any matter causing or contributing to such pollution and shall advise the water pollution agency or interstate agency of the State or States where such discharge or discharges originate of such notification. This notification may outline recommended remedial measures which are reasonable and equitable in that case and

shall specify a reasonable time to secure abatement of the pollution. If action calculated to secure abatement of the pollution within the time specified is not commenced, this failure shall again be brought to the attention of the person or persons discharging the matter and of the water pollution agency or interstate agency of the State or States where such discharge or discharges originate. The notification to such agency may be accompanied by a recommendation that it initiate a suit to abate the pollution in a court of proper jurisdiction.

(3) If, within a reasonable time after the second notification by the Surgeon General, the person or persons discharging the matter fail to initiate action to abate the pollution, or the State water pollution agency or interstate agency fails to initiate a suit to secure abatement, the Federal Security Administrator is authorized to call a public hearing, to be held in or near one or more of the places where the discharge or discharges causing or contributing to such pollution originate, before a board of five or more persons appointed by the Administrator, who may be officers or employees of the Federal Security Agency or of the water pollution agency or interstate agency of the State or States where such discharge or discharges originate (except that at least one of the members of the board shall be a representative of the water pollution agency of the State or States where such discharge or discharges originate and at least one shall be a representative of the Department of Commerce, and not less than a majority of the board shall be persons other than officers or employees of the Federal Security Agency). On the basis of the evidence presented at such hearing the board shall make its recommendations to the Federal Security Administrator concerning the measures, if any, which it finds to be reasonable and equitable to secure abatement of such pollution.

(4) After affording the person or persons discharging the matter causing or contributing to the pollution reasonable opportunity to comply with the recommendations of the board, the Federal Security Administrator may, with the consent of the water pollution agency (or of any officer or agency authorized to give such consent) of the State or States in which the matter causing or contributing to the pollution is discharged, request the Attorney General to bring a suit on behalf of the United States to secure abatement of the pollution.

(5) Before or after any suit authorized by paragraph (4) is commenced, any person who is alleged to be discharging matter contributing to the pollution, abatement of which is sought, may, with the consent of the water pollution agency (or of any officer or agency authorized to give such consent) of the State in which such matter is discharged, be joined as a defendant. The court shall have power to enforce its judgment against any such defendant.

(6) In any suit brought pursuant to paragraph (4) in which two or more persons in different judicial districts are originally joined as defendants, the suit may be commenced in the judicial district in which any discharge caused by any of the defendants occurs.

(7) The court shall receive in evidence in any such suit a transcript of the proceedings before the board and a copy of the board's recommendation; and may receive such further evidence

as the court in its discretion deems proper. The court, giving due consideration to the practicability and to the physical and economic feasibility of securing abatement of any pollution proved, shall have jurisdiction to enter such judgment, and orders enforcing such judgment, as the public interest and the equities of the case may require. The jurisdiction of the Surgeon General, or any other agency which has jurisdiction pursuant to the provisions of this Act, shall not extend to any region or areas nor shall it affect the rights or jurisdiction of any public body where there are in effect provisions for sewage disposal pursuant to agreement between the United States of America and any such public body by stipulation entered in the Supreme Court of the United States. While any such stipulation or modification thereof is in force and effect, no proceedings of any kind may be maintained by virtue of this Act against such public body or any public agency, corporation or individual within its jurisdiction. Neither this provision nor any provision of this Act shall be construed to give to the Surgeon General or any other person or agency the right to intervene in the said proceedings wherein such stipulation was entered.

(8) As used in this subsection, the term "person" includes an individual, corporation, partnership, association, a State, municipality and a political subdivision of a State.

Sec. 3. The Surgeon General may, upon request of any State water pollution agency or interstate agency, conduct investigations and research and make surveys concerning any specific problem of water pollution confronting any State, interstate agency, community, municipality or industrial plant, with a view to recommending a solution of such problem.

Sec. 4. The Surgeon General shall prepare and publish, from time to time, reports of such surveys, studies, investigations, research and experiments made under the authority of this Act as he may consider desirable, together with appropriate recommendations with regard to the control of water pollution.

Sec. 5. The Federal Works Administrator is authorized, subject to the provisions of section 9 (*c*), to make loans to any State, municipality or interstate agency for the construction of necessary treatment works to prevent the discharge by such State or municipality of untreated or inadequately treated sewage or other waste into interstate waters or into a tributary of such waters, and for the preparation (either by its engineering staff or by practicing engineers employed for that purpose) of engineering reports, plans and specifications in connection therewith. Such loans shall be subject, however, to the following limitations: (a) No loan shall be made for any project unless such project shall have been approved by the appropriate State water pollution agency or agencies and by the Surgeon General, and unless such project is included in a comprehensive program developed pursuant to this Act; (b) no loan shall be made for any project in an amount exceeding 33⅓ per centum of the estimated reasonable cost thereof, as determined by the Federal Works Administrator, or in an amount exceeding $200,000, whichever amount is the smaller; (c) every such loan shall bear interest at the rate of 2 per centum per annum, payable semiannually; and (d) the bonds or other obligations evidencing any such loan (1) must be duly authorized and issued pursuant to State

and local law, and (2) may, as to the security thereof and the payment of principal thereof and interest thereon, be subordinated (to the extent deemed feasible and desirable by the Federal Works Administrator for facilitating the financing of such projects) to other bonds or obligations of the obligor issued to finance such project or that may then be outstanding.

Sec. 6. (*a*) The Surgeon General and the Federal Works Administrator, in carrying out their respective functions under this Act, shall provide for the review of all reports of examinations, research, investigations, plans, studies and surveys made pursuant to the provisions of this Act and all applications for loans under section 5. In determining the desirability of projects for treatment works and of approving loans in connection therewith, consideration shall be given to the public benefits to be derived by the construction thereof, the propriety of Federal aid in such construction, the relation of the ultimate cost of constructing and maintaining the works to the public interest and to the public necessity for the works, and the adequacy of the provisions made or proposed by the applicant for the loan for assuring proper and efficient operation and maintenance of the works after completion of the construction thereof.

(*b*) There is hereby established in the Public Health Service a Water Pollution Control Advisory Board to be composed as follows: The Surgeon General or a sanitary engineer officer designated by him, who shall be Chairman of the Board; a representative of the Department of the Army, a representative of the Department of the Interior, a representative of the Federal Works Agency and a representative of the Department of Agriculture, designated by the Secretary of the Army, the Secretary of the Interior, the Federal Works Administrator and the Secretary of Agriculture, respectively; and six persons (not officers or employees of the Federal Government) to be appointed annually by the President. One of the persons appointed by the President shall be an engineer who is expert in sewage and industrial waste disposal, one shall be a person who shall have shown an active interest in the field of wildlife conservation, and, except as the President may determine that the purposes of this Act will be better furthered by different representation, one shall be a person representative of municipal government, one shall be a person representative of State government, and one shall be a person representative of affected industry. The members of the Board who are not officers or employees of the United States shall be entitled to receive compensation at a per diem rate to be fixed by the Federal Security Administrator, together with an allowance for actual and necessary traveling and subsistence expenses while engaged on the business of the Board. It shall be the duty of the Board to review the policies and program of the Public Health Service as undertaken under authority of this Act and to make recommendations thereon in reports to the Surgeon General. Such clerical and technical assistance as may be necessary to discharge the duties of the Board shall be provided from the personnel of the Public Health Service.

Sec. 7. There is hereby authorized to be appropriated to the Federal Security Agency for each of the five fiscal years during the period beginning July 1, 1948, and ending June 30, 1953, a sum not to exceed the sum of

$20,000,000 for the purpose of making loans under section 5 of this Act. Sums so appropriated shall remain available until expended.

Sec. 8. (*a*) There is hereby authorized to be appropriated to the Federal Security Agency for each of the five fiscal years during the period beginning July 1, 1948, and ending June 30, 1953, the sum of $1,000,000, to be allotted equitably and paid to the States for expenditure by or under the direction of their respective State water pollution agencies, and to interstate agencies for expenditure by them, for the conduct of investigations, research, surveys and studies related to the prevention and control of water pollution caused by industrial wastes. Sums appropriated pursuant to this subsection shall remain available until expended, shall be allotted by the Surgeon General in accordance with regulations prescribed by the Federal Security Administrator and shall be paid prior to audit or settlement by the General Accounting Office.

(*b*) There is hereby authorized to be appropriated to the Federal Works Agency for each of the five fiscal years during the period beginning July 1, 1948, and ending June 30, 1953, a sum not to exceed $800,000 to enable the Federal Works Administrator to erect and to furnish and to equip such buildings and facilities at Cincinnati, Ohio, as may be necessary for the use of the Public Health Service in connection with the research and study of pollution of interstate waters and the training of personnel in work related to the control of pollution of interstate waters. The amount authorized for this purpose shall include the cost of preparation of drawings and specifications, supervision of construction and other administrative expenses incident to the work: Provided, That the Federal Works Agency shall prepare the plans and specifications, make all necessary contracts and supervise construction. Sums appropriated pursuant to this authorization shall remain available until expended.

(*c*) There is hereby authorized to be appropriated to the Federal Works Agency for each of the five fiscal years during the period beginning July 1, 1948, and ending June 30, 1953, a sum not to exceed the sum of $1,000,000 to enable the Federal Works Administrator to make grants to States, municipalities or interstate agencies to aid in financing the cost of engineering, architectural and economic investigations and studies, surveys, designs, plans, working drawings, specifications, procedures and other action preliminary to the construction of projects approved by the appropriate State water pollution agency or agencies and by the Surgeon General. Grants made under this subsection with respect to any project shall not exceed whichever of the following amounts is the smaller: (1) $20,000, or (2) 33⅓ per centum of the estimated reasonable cost (as determined by the Federal Works Administrator) of the action preliminary to the construction of such project. Sums appropriated pursuant to this subsection shall remain available until expended.

(*d*) There is hereby authorized to be appropriated to the Federal Security Agency for each of the five fiscal years during the period beginning July 1, 1948, and ending June 30, 1953, such sum (not to exceed the sum of $2,000,000) as may be necessary to enable it to carry out its functions under this Act.

(*e*) There is hereby authorized to be appropriated to the Federal Works

Agency for each of the five fiscal years during the period beginning July 1, 1948, and ending June 30, 1953, such sum (not to exceed the sum of $500,-000) as may be necessary to enable it to carry out its functions under this Act.

Sec. 9. (*a*) To assist in carrying out the purposes of this Act, the appointment of engineer and scientist officers may be made under the provisions of section 208 (b) (1) of the Public Health Service Act, in addition to the appointments authorized by such section 208 (b) (1); but not more than five such additional officers shall hold office at the same time.

(*b*) The Federal Security Administrator, with the consent of the head of any other agency of the Federal Government, may utilize such officers and employees of such agency as may be found necessary to assist in carrying out the purposes of this Act.

(*c*) (1) Upon written request of the Federal Works Administrator, from time to time submitted to the Federal Security Administrator, specifying (a) particular projects approved by the Surgeon General, (b) the total estimated costs of such projects and (c) the total sum requested for loans which the Federal Works Administrator proposes to make for such projects, the Federal Security Administrator shall transfer such total sum (within the amount appropriated therefor) to the Federal Works Administrator for the making of loans for such projects pursuant to section 5 hereof. In making such loans, the Federal Works Administrator shall adhere to the order or sequence of priority for projects established by the Surgeon General and shall take such measures as, in his judgment, will assure that the engineering plans and specifications, the details of construction and the completed treatment works conform to the project as approved by the Surgeon General; and the Federal Works Administrator shall furnish written reports to the Federal Security Administrator on the progress of the work.

(2) The Federal Works Administrator is hereby authorized (a) to hold, administer, exchange, refund or sell at public or private sale any bonds or other obligations evidencing loans made under this Act; and (b) to collect, or provide for the collection of, interest on and principal of such bonds or other obligations. All moneys received as proceeds from such sales, and all moneys so collected, shall be covered into the Treasury as miscellaneous receipts.

(*d*) The Surgeon General and the Federal Works Administrator are each authorized to prescribe such regulations as are necessary to carry out their respective functions under this Act.

Sec. 10. When used in this Act:

(*a*) The term "State water pollution agency" means the State health authority, except that, in the case of any State in which there is a single State agency, other than the State health authority, charged with responsibility for enforcing State laws relating to the abatement of water pollution, it means such other State agency;

(*b*) The term "interstate agency" means an agency of two or more States having powers or duties pertaining to the abatement of pollution of waters;

(*c*) The term "treatment works" means the various devices used in the treatment of sewage or industrial waste of a liquid nature, including the necessary intercepting sewers, outfall sewers, pumping, power and other equipment,

and their appurtenances, and includes any extensions, improvements, remodeling, additions and alterations thereof;

(*d*) The term "State" means a State, the District of Columbia, Hawaii, Alaska, Puerto Rico or the Virgin Islands;

(*e*) The term "interstate waters" means all rivers, lakes and other waters that flow across, or form a part of, State boundaries; and

(*f*) The term "municipality" means a city, town, district or other public body created by or pursuant to State law and having jurisdiction over disposal of sewage, industrial wastes or other wastes.

Sec. 11. This Act shall not be construed as (1) superseding or limiting the functions, under any other law, of the Surgeon General or of the Public Health Service, or of any other officer or agency of the United States, relating to water pollution, or (2) affecting or impairing the provisions of the Oil Pollution Act, 1924, or sections 13 through 17 of the Act entitled "An Act making appropriations for the construction, repair and preservation of certain public works on rivers and harbors and for other purposes," approved March 3, 1899, as amended, or (3) affecting or impairing the provisions of any treaty of the United States.

Sec. 12. If any provision of this Act, or the application of any provision of this Act to any person or circumstance, is held invalid, the application of such provision to other persons or circumstances, and the remainder of this Act, shall not be affected thereby.

Sec. 13. This Act may be cited as the "Water Pollution Control Act."